Memo

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Date: 6 Feb. 2014
To: Chris DiMatteo, Assistant Town Planner, Town of Kittery
From: Robert Gerber, PE
Subject: Preliminary review of FEMA Preliminary Coastal Flood Maps

Introduction

As agreed with the Town, I have undertaken a preliminary review of the Preliminary coastal flood maps and underlying calculations produced by FEMA that support the Nov. 2013 Preliminary York County Flood Map release for the area between Seavey Island and Gerrish Island.

I have printed out pertinent information from the "engineering data disk" and annotated it in places. The Town probably does not have the software to load and print out a lot of the material that I have printed, so this will give you a good record of what calculations underlie the maps.

The set of attachments appended to this report includes some basic town-wide information and then groups most of the underlying technical calculations by transects. FEMA uses some broad-based modeling approaches to develop characteristic wave-related inputs to "transects". It then calculates a number of things along these linear transects and then turns that into a flood map that incorporates that data and interpolates that data between transects. This report and attachments are bookmarked in Adobe PDF format so turn on the bookmarks in the vertical menu bar on the left and you can navigate quickly through the document.

Basic Mapping and Underlying Wave Data

Attachment 1 is a map of the study area showing the wave transects and proposed FEMA zones overlain on USGS topographic base maps. That is followed by a printout (**Attachment 2**) of the detailed FEMA STWAVE model 100-year significant wave height contours. **Attachment 3** contains the pertinent parts of the FEMA "Engineering Summary" Excel spreadsheet contained on the data disk. This consists of 5 pages that reference the FEMA transects as shown on the maps. The wave transects we evaluated in Kittery are numbered sequentially from YK-02 in the west to YK-09 in the east. However, most of the analyses on these transects were done in 2007 when the transects were numbered from east to west and prefaced by "KT". The correspondence table is as follows:

New Transect Number	Old Transect Number
YK-02	KT-15
YK-03	KT-13
YK-04	KT-14
YK-05	KT-12
YK-06	KT-11
YK-07	KT-10
YK-08	KT-9
YK-09	KT-8

We point out that the wave contour map in **Attachment 2** shows the contoured output of FEMA's detailed STWAVE wave model. The purple lines are contours of equal wave height in feet (as shown by the labels). This wave height is the "significant" wave height which is used in many of the FEMA calculations. The significant wave height is the average of the 1/3rd highest waves during the peak of the 100-year storm condition. Where the wave contours are close together it indicates that the large offshore waves are breaking due to shoaling on the bottom. Notice that because the topography of the land area was not properly represented, the waves are shown to go into and through the land for significant distances, which they would not actually do. The waves should stop at the 100-year storm surge elevation, which is defined in FEMA's tables and the draft FIS as elevation 9.2' NAVD88 vertical datum. However, FEMA's wave model assumes a slightly higher elevation on which the waves are superimposed of 9.5' NAVD88 (because that is what the future SWEL will be after the new maps are adopted—but it is not what these Preliminary maps should be based on).

Wave Transect Calculations

Beginning with **Attachment 4** and proceeding through **Attachment 11** the FEMA model printouts are arranged by transect going from west to east in the study area. There are several sets of documents for each transect. The usual order is to present the WHAFIS Wave Profile, then the Restricted Fetch Analysis (estimate of wave heights derived from local winds), then the Transect General Information, then MathCAD printouts of wave setup (which may include wave setup on "structures" or steep slopes), then any wave runup calculation that may have been provided, and finally the FEMA "wave envelope" that might occur on that transect, and the wave runup on that transect if the "TAW" method was used. The transect may have results that include cases for both the “intact” and “failed” conditions if the transect goes through a shoreline protection structure.

The total wave setup is entered as input to the FEMA CHAMP model, which has a set of modules that calculate the wave crest profile (based on the elevation of the top of the wave crests for the average of the 1% highest waves), and if the shore slope is less than 12.5% the RUNUP2 module should be used to calculate runup rather than the TAW or SPM method. The RUNUP2 runs are stated in **Attachment 3** to be unreliable. Final Runup is based on the average of the 2% highest wave runup position. The TAW method is generally applied to steep banks and riprap. The SPM method is applied to only vertical walls. For riprap and bulkhead walls, FEMA usually calculates the intact case (for the wall profile the way it currently exists) and the “failed” case where FEMA assumes certain standard modes of failure. If a property owner’s flood zone and Base Flood Elevation (BFE) is based on the assumption of a “failed” wall and the owner can obtain a Licensed Professional Engineer to “certify” that the wall can withstand the 100-year storm, then an appeal could be filed on that basis.

FEMA uses the results from the “intact” versus “failed” structure analyses to choose which of the two cases—intact or failed—produces the higher of the two runups and then uses that value to set the Base Flood Elevations (BFE) on the ocean side of the structures. If the top of the structure elevation is less that the surge elevation plus runup, then the runup is supposed to be capped at top of structure (or top of bank in case of failed structure) plus 3’. Splash zones 30’ wide may be included behind intact structures or behind the top of a bank.

The New Issue: Wave Setup and its transmission into the Estuarine Areas

One additional feature of the new Preliminary Maps must be pointed out because the carrying of the calculated term “wave setup” into the back estuary areas (only near YK-04 in the study area) is something new on these maps that did not occur on the 2009 Preliminary FEMA maps. The basis for doing this comes from a section buried deep in FEMA’s Guidelines and Specifications (G&S), Appendix D, Section 2.6.3.4 of the *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update* (Feb. 2007). Unless expensive modeling of a type that FEMA did not include in its budget to map York County is done, the following guideline controls:

> **D.2.6.3.4.3 Decay of Wave Setup across Flooded Lands**
>
> Some previous Flood Insurance Studies have been completed using the assumption that wave setup will decay in the inland direction at some prescribed rate (e.g., one foot of wave setup decay per 1,000 ft of inland flooding, or all wave setup will decay across the barrier island width, etc.). These rules of thumb should not be used. Absent the types of 2-dimensional effects described in the previous section, wave setup at the inland limit of flooding will be equal to or greater than the wave setup at the +/- MSL shoreline

Some of the Kittery transects have an assumed offshore significant wave height of 29.9' and a wave period of 11.4 seconds which is the offshore "deepwater" wave characteristic. However, three transects (YK-02, YK-03, and YK-04) calculate setup based on locally derived wind-generated waves (based on 71 mph wind). The Direct Integration Method (DIM) methodology of calculating open ocean wave setup requires, according to FEMA, the use of a "deepwater wave" height and period. The sum of the surge elevation and the wave setup is called the Total Water Level or TWL, and this is carried into estuaries. On top of this, additional feet of flood elevation may be added for locally-generated wave crests and/or wave runup.

Transect Discussions

YK-02 uses an incorrect wave height to do the WHAFIS and runup calculations, regardless of whether you use the Restricted Fetch analysis or the STWAVE model. I have no idea where the 7.55 foot significant wave height came from, but it is too high and produces a Base Flood Elevation (BFE) that is too high. The analysis should be re-done using the restricted fetch calculated wave height and the results from a revised STWAVE model. The result from the analysis that produces the highest BFE will control.

YK-03 again uses an incorrect wave height for the WHAFIS and runup calculations. It is a mystery as to where the wave height came from. The analysis should be re-done using the restricted fetch calculated wave height and the results from a revised STWAVE model.

YK-04 needs to be re-done from scratch, if only to resolve discrepancies among different FEMA sources of data. The WHAFIS input data says H = 2.95'; the restricted fetch analysis derived an H of 3.49'; and the FEMA summary table states 1.64' was used for H. The analysis should be re-done using the restricted fetch calculated wave height and the results from a revised STWAVE model.

YK-05 uses a deepwater wave height of 29.86'. WHAFIS and TAW should use locally-derived waves based on either the restricted fetch analysis or the detailed STWAVE model (they have quite different wave periods so usually both have to be run and the larger of the two taken). It is also my firm belief that wave setup should be calculated based on what the local wave height is, not the 30' offshore wave due to the protection of this harbor and the fact that the 3 sections to the west use locally derived wave heights and based on other locations such as Plymouth Harbor on the south shore of Boston where local wave heights were used by FEMA.

YK-06 again uses the 30' deepwater wave height for wave setup calculations although I do not agree with that. WHAFIS and TAW calculations should be based on local waves not the deepwater wave heights. FEMA specifications call for capping the VE BFE at no higher than 3' over the top of a bank where the bank is overtopped and FEMA did not do this in this section and thus overstated the VE elevation.

YK-07 again uses the 30’ deepwater wave height for wave setup calculations although I do not agree with that. WHAFIS and TAW calculations should be based on local waves not the deepwater wave heights. Fishing Island provides a lot of protection for this area so the “restricted fetch” analysis should not really be used, but rather the 2-dimensional STWAVE model results.

YK-08 again uses the 30’ deepwater wave height for wave setup calculations although I do not agree with that. WHAFIS and TAW calculations should be based on local waves not the deepwater wave heights. For some reason, no runup analysis was provided, although the engineering summary tables suggested that the TAW method was used.

YK-09 again uses the 30’ deepwater wave height for wave setup calculations although I do not agree with that. WHAFIS and TAW calculations should be based on local waves not the deepwater wave heights. The wave setup is stated to be 6.5’ in one place, 7.9’ in another place and 7.2’ in another place and in my opinion those are all too high. No runup evaluation was provided.

Summary of Issues found that may warrant Follow-up

1. Kittery was one of the first towns calculated by FEMA in 2007 and frankly, it was not done well at all. FEMA only did its STWAVE model recently so it was not available back in 2007. Although FEMA made some recent adjustments to increase the offshore wave heights for the purpose of calculating wave setup, a common sense application of FEMA’s Guidelines and Specifications was not made. Therefore, we suggest that all transects should be completely re-calculated after the STWAVE model is re-tooled to put the shoreline in the correct position and the surge elevation is adjusted to 9.2’ NAVD88.

2. STWAVE model improvement and better incident wave selection for WHAFIS and TAW. The wave model does not properly reflect the topography of the study area above surge elevation as shown in **Attachment 2**. Putting in the actual topography on land above the surge elevation would result in improved wave modeling. LiDAR and 2-ft contours for that area are available on the MEGIS website. Although FEMA insists on using the deepwater wave characteristics to calculate wave setup, smaller near-shore waves should be used as inputs to WHAFIS, TAW and SPM. The surge elevation of 9.2’ should be used in the STWAVE model, not 9.5’. The nearshore wave heights vary depending on the transect and in some cases both the fetch-derived wave characteristics and the STWAVE results should both be used for WHAFIS and TAW, to see which controls.

   We note that FEMA used the full deepwater (e.g., ≥300’ water depth) wave heights in both WHAFIS and wave runup calculations. As noted in Section D.2.7.1 of the February 2007 Guidelines and Specifications for Flood Hazard Mapping Partners (Atlantic Ocean and Gulf of Mexico Coastal Guidelines

Update) (**Attachment 12**) WHAFIS is not intended to use a wave characteristic derived from 10 miles offshore if the wave is transformed by “refraction, diffraction, or bottom dissipation effects.” The section goes on to state that “the Mapping Partner should perform separate wave transformation calculations if these effects will cause the incident wave height to depart markedly from the value generated (WHAFIS originally generated the wave characteristics by simulating a wind of constant velocity blowing across a fetch of defined length) by WHAFIS.” This is a benefit of using the STWAVE model to create a distribution of significant wave heights and periods across the coastal area being mapped. It does take into account refraction and bottom dissipation effects and, to a mild degree, diffraction.

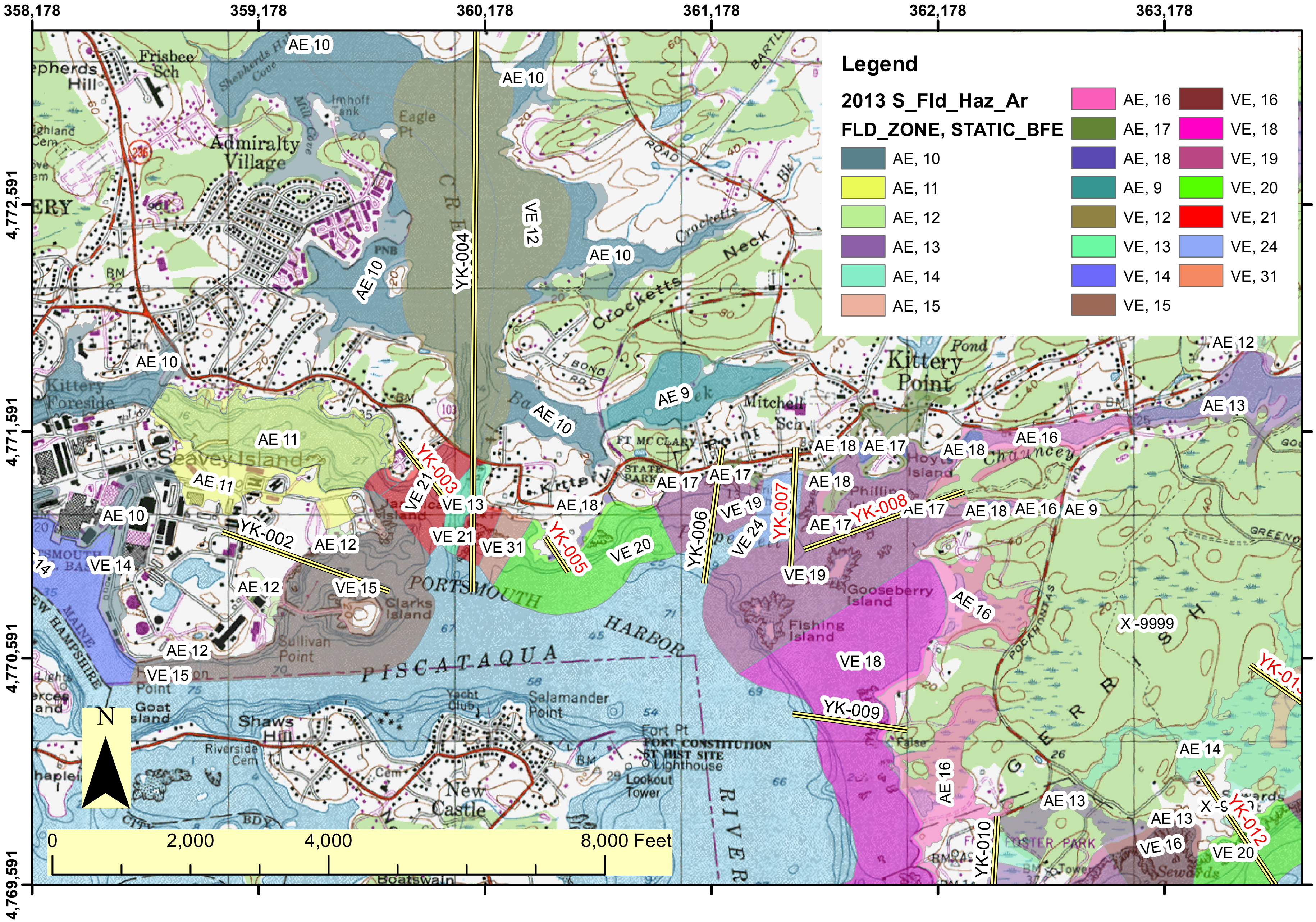
Similarly, FEMA used the deepwater wave height for its TAW runup calculations. See **Attachment 13,** Page 2 of the “Technical Report, Wave Run-Up and Wave Overtopping at Dikes” published by the Technical Committee on Flood Defence at Delft in May 2002 (which documents the TAW methodology), “the wave height that is always used in wave run-up and wave overtopping calculations is the incident wave height that should be expected at the end of the foreshore (and thus at the toe of the dike).” This is definitely <u>*not*</u> the deepwater wave of 29.9’.

3. <u>The choice of wave height for the calculation of wave setup should be provided with backup from historical storm records if possible.</u> If wave setup controls (instead of wave runup) in a critical area, it may be worthwhile to try to simulate the February 1978 storm conditions and compare the single measured Total Water Level with a value predicted by reconstructing the wave conditions from the February 1978 storm (data point 101) and then calculating the wave setup at the wave transect of interest. The point on Chauncey Creek from 1978 had a measured elevation of 9.01’ NAVD88.

   This could then be used to argue that the classic DIM calculations over-predicted the wave setup. The problem remains of how to translate this to the theoretical 100-year storm. It may be possible to develop a defensible way of scaling up the results of measured storm TWL measurements to the theoretical 100 year storm, but we have not thought through that process in enough detail yet to determine what would be required.

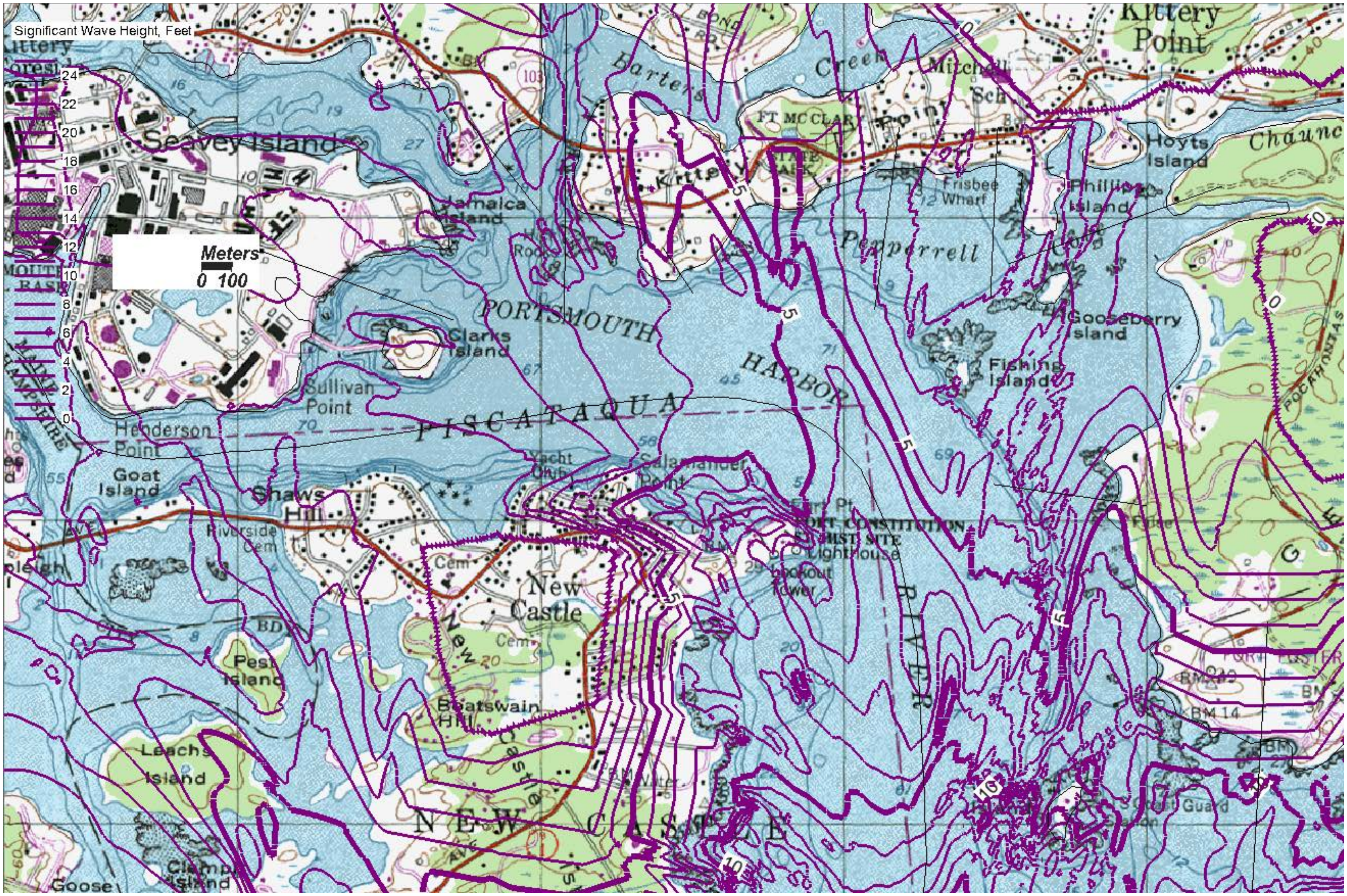
Estimated Cost to fix STWAVE model and re-run all transects and produce new map of the study area is $20,000.

Attachments: 1-13



FEMA 2013 Preliminary Flood Map and Transects
Kittery, Maine
Grid is UTM, NAD83, 19N, meters; Base Map USGS 7.5' Topo Sheet
RGG 141.06006 2/4/14

RANSOM Consulting, Inc.



FEMA Detailed Wave Model Output as contours of the Significant Wave Height, Hs, in Feet. 10 meter by 10 meter grid cells. Notice the topography of the land is not properly represented, allowing the waves to extend into the land where the waves cannot go.

		Deep Water Wave Height								Average Transect Slope			
Community Transect ID	STARR Transect ID	SWEL	STWAVE Model Used	Wave Height (m)	Wave Height (ft)	Wave Period	Wave Length	H_b	d_b	Toe / Breaking Wave Height Elevation	Top / SWEL Elevation	Toe Station	Top / SWEL Station
KT-10	YK-07	9.2	Wells_100yr	9.1	29.86	11.40	666.0	25.5	32.7	-23.5	9.2	N/A	49.0
KT-11	YK-06	9.2	Wells_100yr	9.1	29.86	11.40	666.0	25.5	32.7	-23.5	9.2	N/A	39.0
KT-12	YK-05	9.2	Wells_100yr	9.1	29.86	11.40	666.0	25.5	32.7	-23.5	9.2	N/A	19.0
KT-13	YK-03	9.2	Wells_100yr	2.3	7.55	10.00	512.5	9.3	12.0	-2.8	9.2	N/A	100.0
KT-14	YK-04	9.2	Wells_100yr	0.5	1.64	7.90	319.8	2.9	3.7	5.5	9.2	N/A	97.0
KT-15	YK-02	9.2	Wells_100yr	2.3	7.55	10.00	512.5	9.3	12.0	-2.8	9.2	N/A	58.0
KT-8	YK-09	9.2	Wells_100yr	9.1	29.86	11.40	666.0	25.5	32.7	-23.5	9.2	N/A	214.0
KT-9	YK-08	9.2	Wells_100yr	9.1	29.86	11.40	666.0	25.5	32.7	-23.5	9.2	N/A	30.0

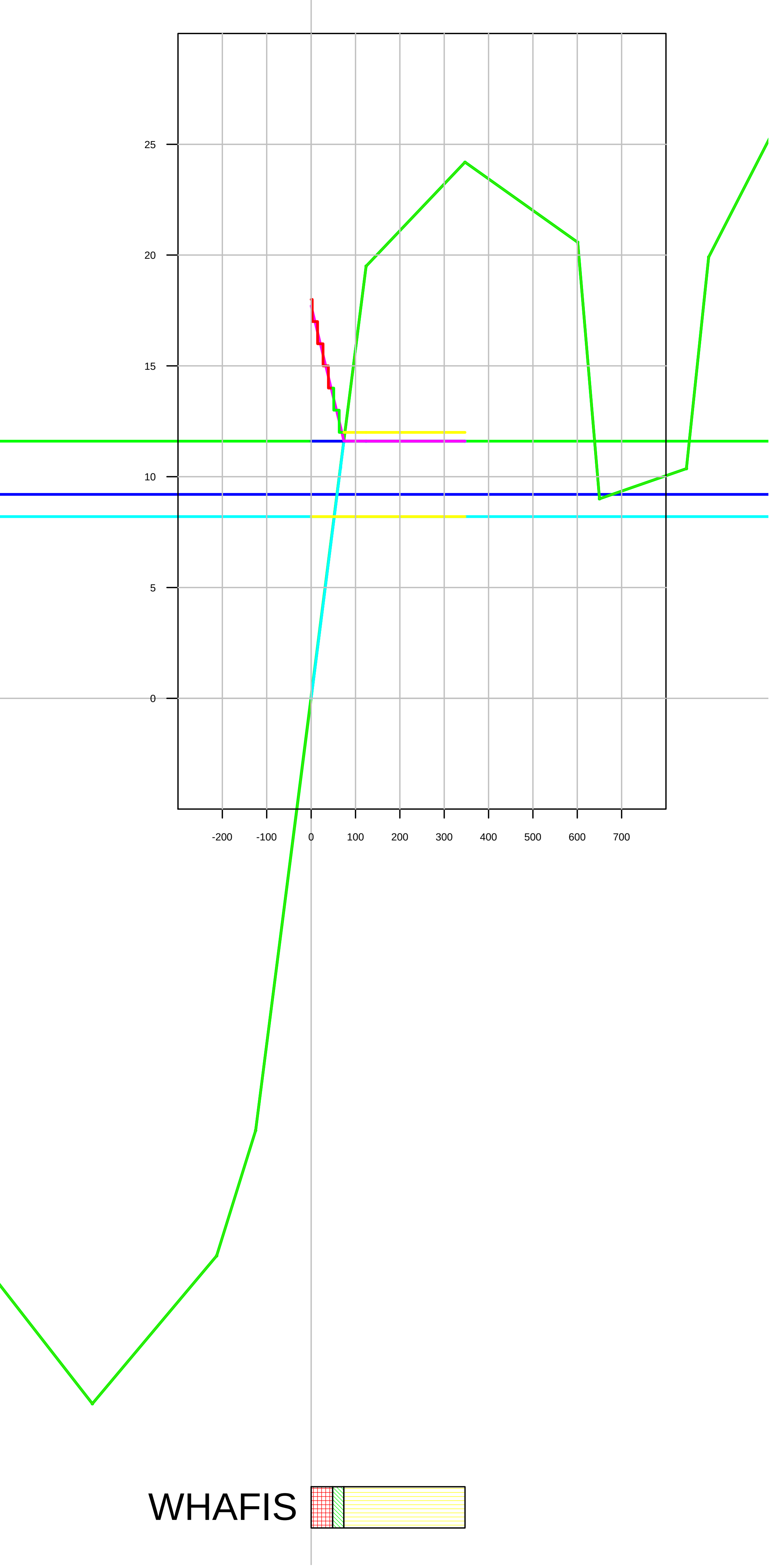
				Average Shore Slope		Wave Setup			Wave Runup		
Community Transect ID	STARR Transect ID	Average Transect SLOPE, m	1:ON	Average Beach Slope	1:ON	Open, h_{open} (ft)	With Structure $h_{structure}$ (ft)	Total Water Level	Runup 2% (ft)	Method	Overtopped?
KT-10	YK-07	0.2000	5.0	0.2	*5.3*	6.4	7.9	17.1	26.0	RUNUP 2.0 UNRELIABLE, TAW	YES
KT-11	YK-06	0.2000	5.0	0.2	*4.2*	6.4	7.4	16.6	4.8	TAW invalid, RUNUP 2.0	NO
KT-12	YK-05	0.5000	2.0	0.5	*2.1*	7.7	8.5	17.7	22.1	TAW	YES
KT-13	YK-03	0.0909	11.0	0.1	*10.9*	1.7		10.9	11.5	TAW Surf Zone (MATLAB)	YES
KT-14	YK-04	0.0833	12.0	0.1	*10.5*	0.7		9.9	9.8	RUNUP 2.0, TAW INVALID	YES
KT-15	YK-02	0.1667	6.0	0.2	*6.3*	2.0	2.4	11.6	10.5	RUNUP 2.0 UNRELIABLE, TAW	YES
KT-8	YK-09	0.2500	4.0	0.0	*23.3*	6.7	6.5	15.7	9.5	RUNUP 2.0 UNRELIABLE, TAW	YES
KT-9	YK-08	0.3333	3.0	0.3	*3.3*	7.1	7.2	16.4	10.2	RUNUP 2.0 UNRELIABLE, TAW	YES

		Structure Analysis									
Community Transect ID	STARR Transect ID	Does Structure Exist?	Revetment or Vertical Structure?	Runup Elevation (ft)	Armor Depth	Intact **Toe** of Structure **Elevation** (ft)	Intact **Top** of Structure **Elevation** (ft)	Intact **Toe Station**	Intact **Top Station**	Failed **Top Station**	Failed **Top Elevation**
KT-10	YK-07	NO	None	35.2		-2.0	20.9	0.0	98.0		
KT-11	YK-06	YES	Revetment	14.0		5.7	16.6	42.0	55.2	64.1	16.7
KT-12	YK-05	NO	None	31.3		0.7	14.4	1.0	42		
KT-13	YK-03	NO	None	20.7		1.7	14.9	60.0	118.0		
KT-14	YK-04	NO	None	19.0		2.7	17.1	5.0	141.0		
KT-15	YK-02	NO	None	19.7		4.9	19.5	20.0	124.0		
KT-8	YK-09	NO	None	18.7		5.4	13.6	200.0	223.0		
KT-9	YK-08	NO	None	19.4		5.3	14.3	18.0	77.0		

						Notes		
Community Transect ID	STARR Transect ID	Notes	Maximum Wave Crest Elevation Simulated by WHAFIS (ft)	VE Zone Break Elevation (ft)	Basis of Mapping Decision	SURVEY	SWEL/TWEL	STRUCTURE
KT-10	YK-07							
KT-11	YK-06							
KT-12	YK-05							
KT-13	YK-03							
KT-14	YK-04							
KT-15	YK-02							
KT-8	YK-09							
KT-9	YK-08							

		on Engineering Decisions					
Community Transect ID	STARR Transect ID	FAILURE	EROSION	RUNUP	WHAFIS INTACT	WHAFIS FAILED	Mapping comments
KT-10	YK-07		No	Updated from Runup2.0 MapMod to using TAW. 4/1/2013			
KT-11	YK-06		No	TAW method invalid based on structure slope. RUNUP 2.0 used instead.			
KT-12	YK-05		No				
KT-13	YK-03		No				
KT-14	YK-04		No				
KT-15	YK-02		No	Updated from Runup2.0 MapMod to using TAW. 4/1/2013	Ballfield behind structure. Not hydr. Connected.		
KT-8	YK-09		No	Updated from Runup2.0 MapMod to using TAW			
KT-9	YK-08		No	Updated from Runup2.0 MapMod to using TAW. 4/1/2013			

YK-02
KT-15



Project: Fema Study- York County, ME
Group: KT-15 YK-02

Case: KT-15

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	1.69	MILES
Wind Direction (WDIR)	108.93	deg
Eq Neutral Wind Speed (Ue)	63.89	mph
Adjusted Wind Speed (Ua)	104.27	mph
Mean Wave Direction (THETA)	105.00	deg
Wave Height (Hmo)	3.81	feet
Wave Period (Tp)	3.55	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	58.93	0.11
2	68.93	0.21
3	78.93	0.59
4	88.93	0.63
5	98.93	1.71
6	108.93	1.74
7	118.93	1.01
8	128.93	0.64
9	138.93	0.57
10	148.93	0.60
11	158.93	0.45

Wave Growth: Deep

YK-02

Transect General Information - Transect ID: KT-15

Description | **Parameters**

Flooding Source	Portsmouth Harbor		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	7.55		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	10		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	2.4	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDDF		1% WINDIF	
0.2 % WINDDF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-15

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 7.5\,ft$ Deepwater significant wave height (determined from STWAVE)

$T := 10\,sec$ Peak wave period (determined from STWAVE)

$m := \frac{1}{6}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $Lo = 512.1\,ft$

$\frac{Ho}{Lo} = 0.015$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 1.95\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

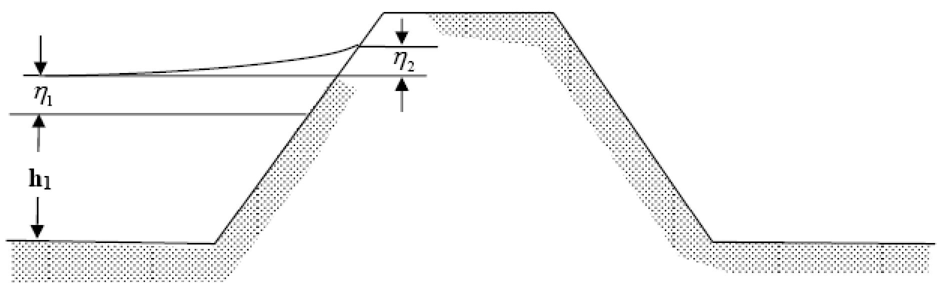


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-15 (Steep Slope)

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 1.95ft$ Wave setup without structure (From DIM MathCAD sheet for KT-15)

$h_1 := 4.35ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 10 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 7.5ft$ Deep water significant wave height in feet (from STWAVE)

$C := 19.5ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \frac{g \cdot T^2}{2 \cdot \pi}$ Deep water wave length $L_o = 512.1\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.015$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

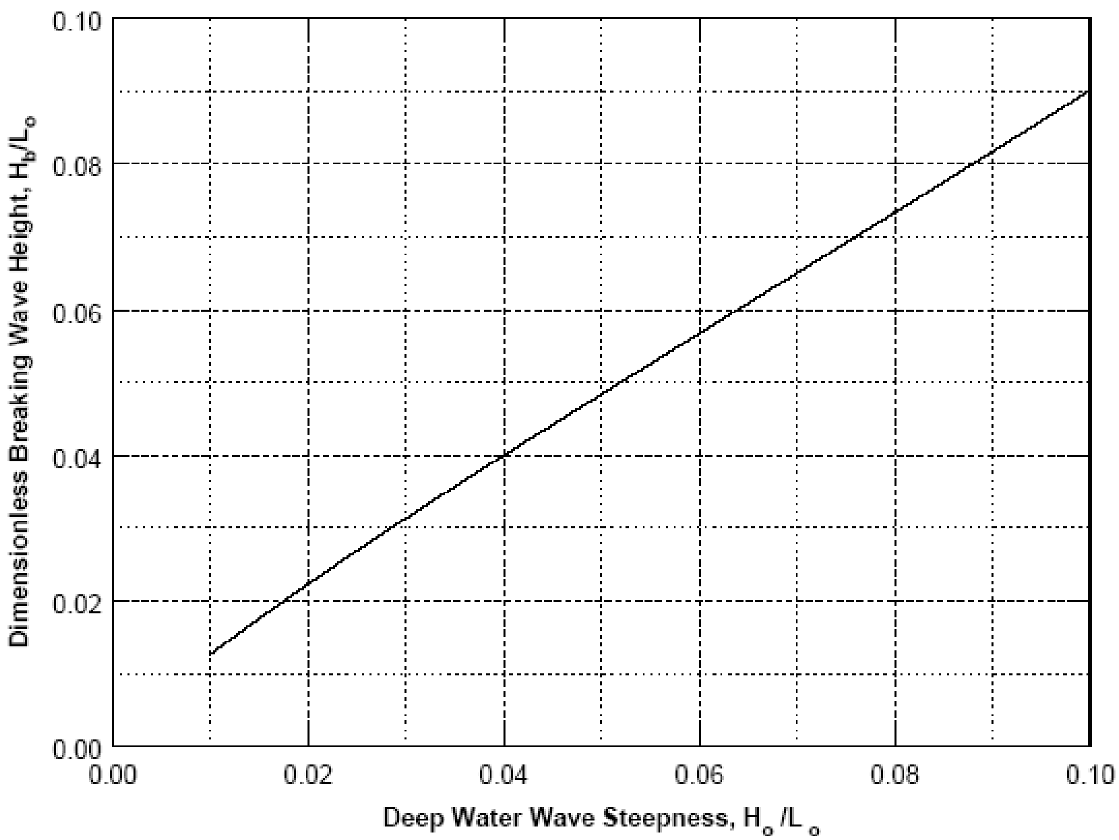


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.018$

$H_b := b_h \cdot L_o$

$H_b = 9.3\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

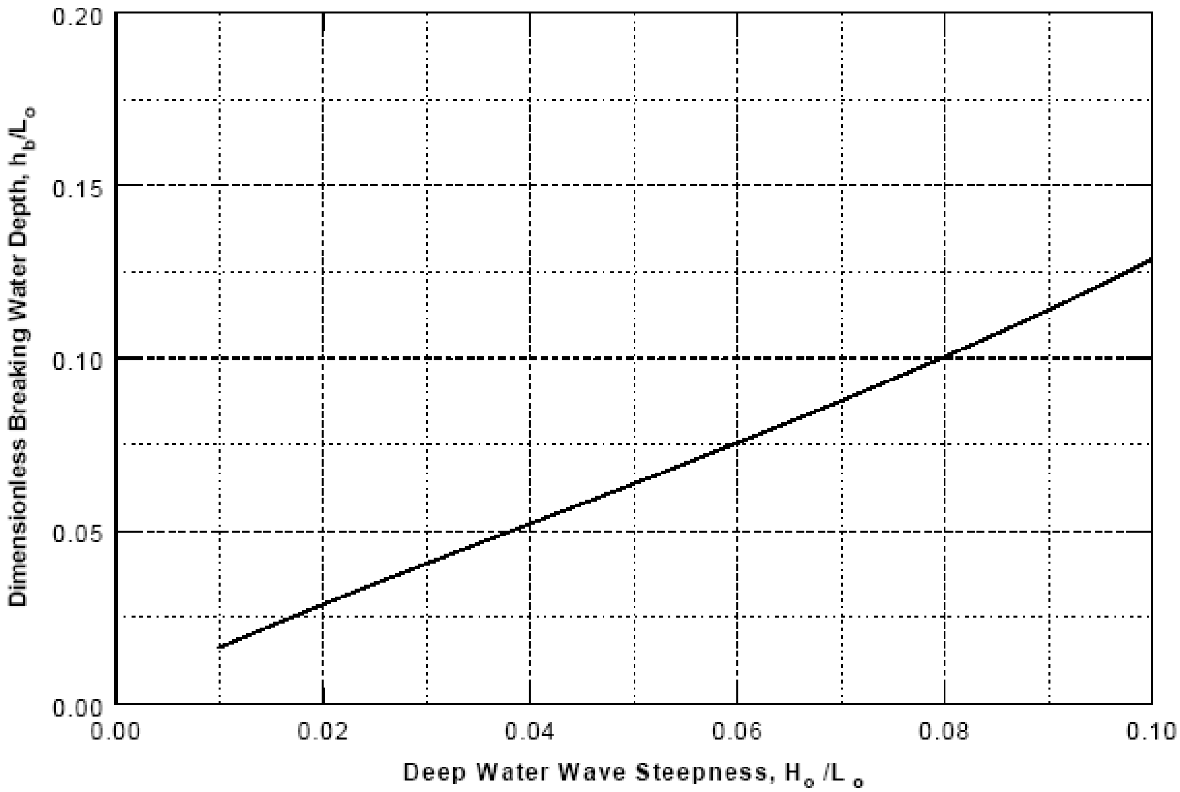


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d = h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.021$

$h_b := b_d \cdot L_o$

$h_b = 10.8\,\text{ft}$

STEP 4: CALCULATE WAVE SETUP

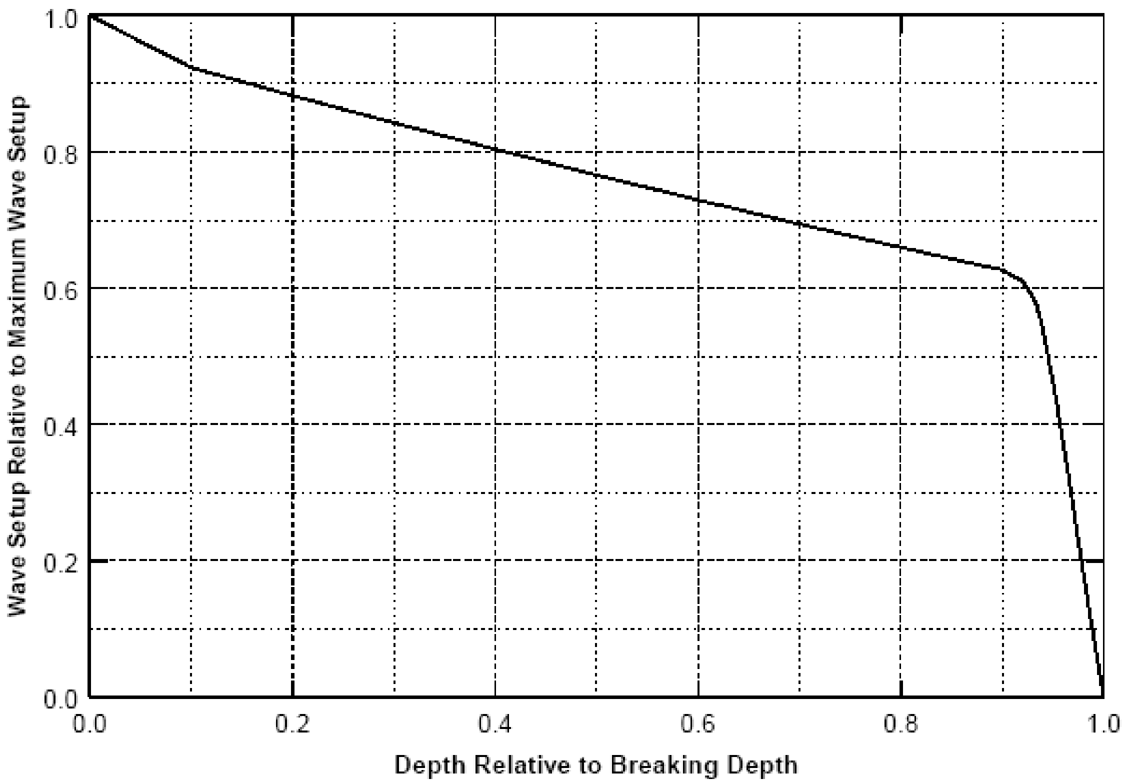


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio $\left(R := \frac{\eta_1}{\eta_{max}}\right)$

$$R := \begin{cases} \left[-0.8\cdot\left(\frac{h_1}{h_b}\right)+1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\ \left[-0.3919\cdot\left(\frac{h_1}{h_b}\right)+0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\ \left[-0.3475\cdot\left(\frac{h_1}{h_b}\right)+0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\ \left[-33.312\cdot\left(\frac{h_1}{h_b}\right)^2+59.811\cdot\left(\frac{h_1}{h_b}\right)-26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\ \left[-9.8703\cdot\left(\frac{h_1}{h_b}\right)+9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1 \end{cases}$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.4$ $\qquad R = 0.8$

$\eta_1 := R \cdot \eta_{max}$ $\qquad \eta_1 = 1.56\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\qquad \eta_2 = 0.89\,ft$

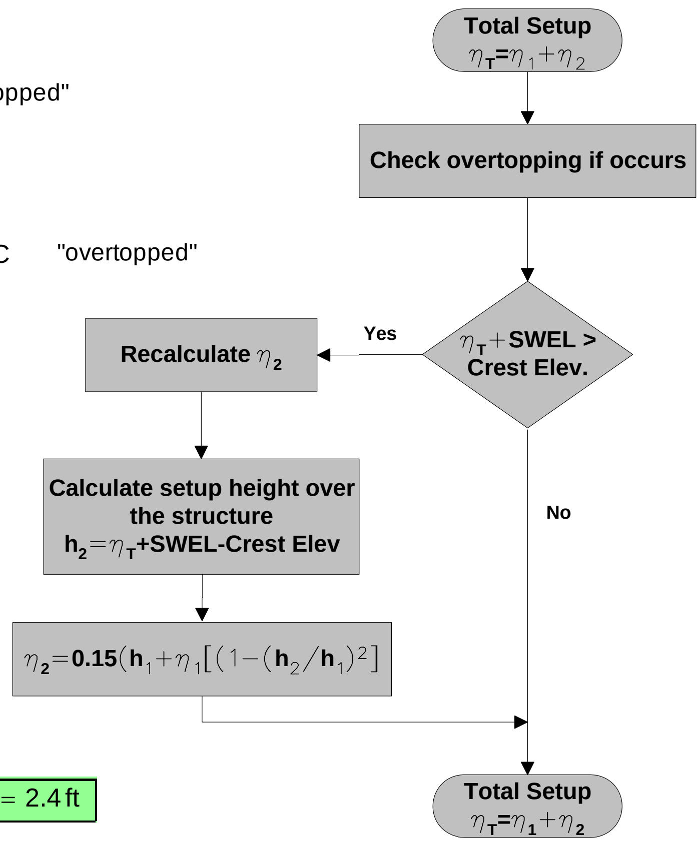
Total Setup $\qquad \eta_T := \eta_1 + \eta_2$ $\qquad \eta_T = 2.4\,ft$

Check overtopping

$$OVERTOPPED := \begin{vmatrix} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{vmatrix}$$

$$h_2 := \begin{vmatrix} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{vmatrix}$$

$$\eta_2 := \begin{vmatrix} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{vmatrix}$$



Flowchart for overtopping check

OVERTOPPED = "NO"

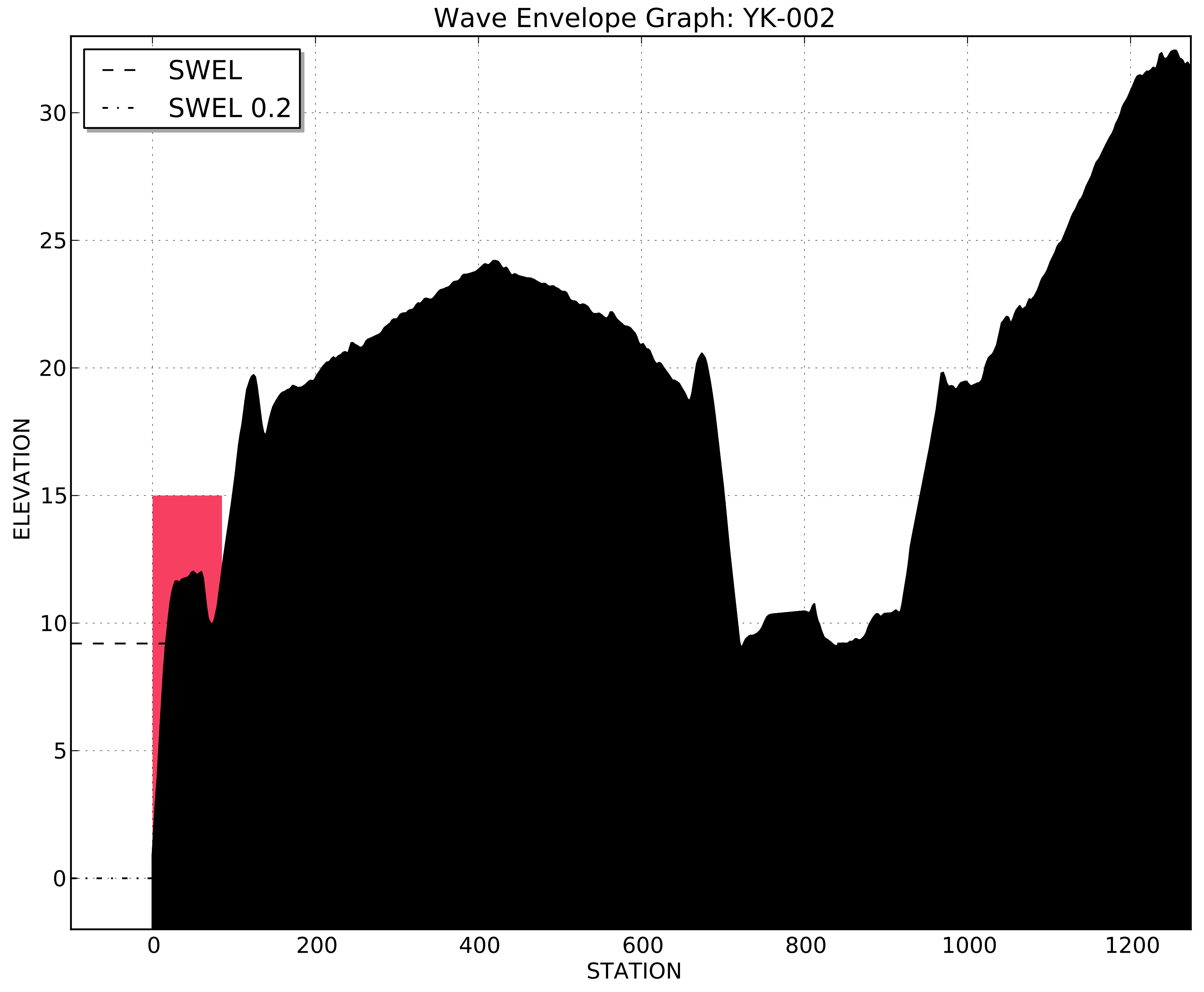
$h_2 = 0\,ft$

$\eta_1 = 1.56\,ft$

$\eta_2 = 0.89\,ft$

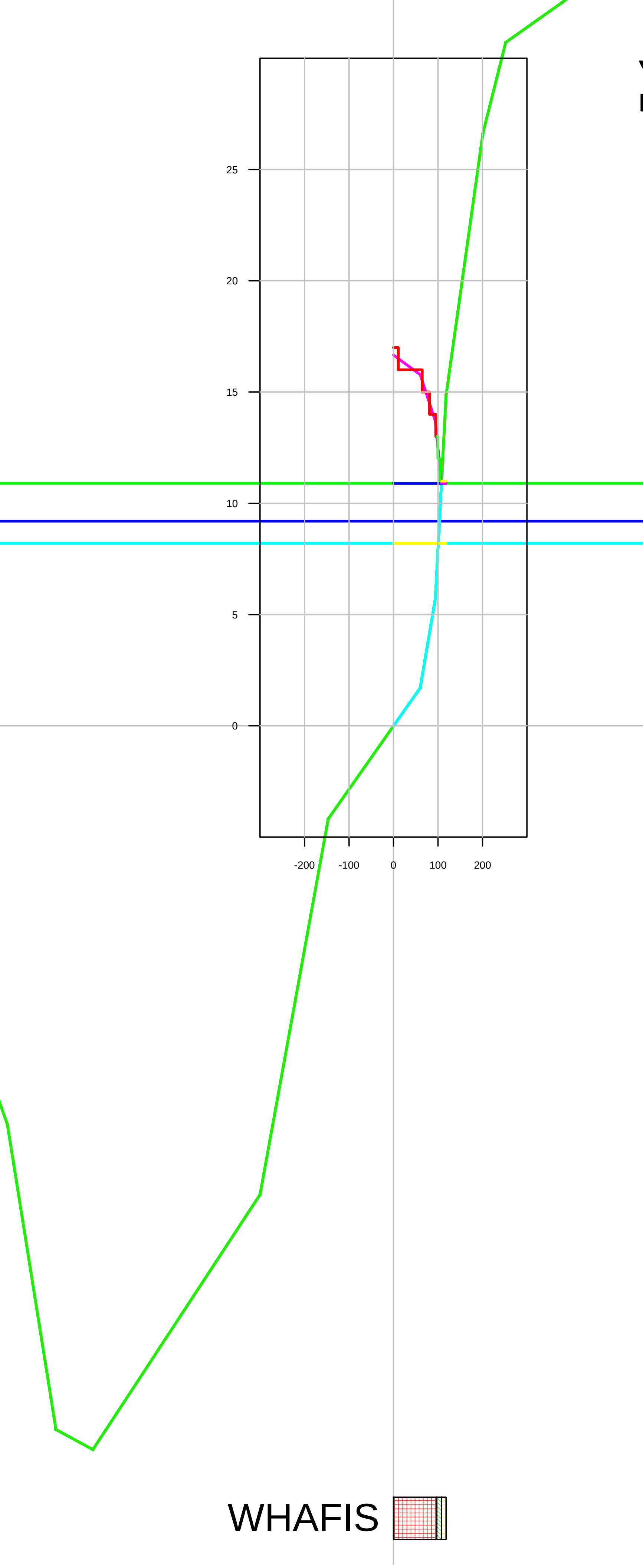
Total Final Wave Setup $\qquad \eta_T := \eta_1 + \eta_2$ $\qquad \eta_T = 2.4\,ft$

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.



Wave Envelope Graph: YK-002
SWEL
SWEL 0.2
ELEVATION
STATION
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200

YK-03
KT-13



Project: Fema Study- York County, ME
Group: KT-13 YK-03

Case: KT-13

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	15.22	MILES
Wind Direction (WDIR)	141.13	deg
Eq Neutral Wind Speed (Ue)	70.99	mph
Adjusted Wind Speed (Ua)	120.39	mph
Mean Wave Direction (THETA)	131.00	deg
Wave Height (Hmo)	8.59	feet
Wave Period (Tp)	5.59	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	91.13	0.18
2	101.13	0.17
3	111.13	0.17
4	121.13	0.18
5	131.13	24.00
6	141.13	0.94
7	151.13	0.88
8	161.13	0.68
9	171.13	0.68
10	181.13	0.79
11	191.13	0.71

Wave Growth: Deep

YK-08

Transect General Information - Transect ID: KT-13

Description | **Parameters**

Flooding Source	Portsmouth Harbor		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	7.55		
0.2% Significant Wave Height (ft)			
1% Deepwater Wave Period (sec)	10	Method for determing wave setup magnitude	Direct Integration Method (DIM)
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	1.7	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-13

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 7.5\,ft$ Deepwater significant wave height (determined from STWAVE)

$T := 10\,sec$ Peak wave period (determined from STWAVE)

$m := \frac{1}{11}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2 \cdot \pi}$ Deep water wave length $Lo = 512.1\,ft$

$\frac{Ho}{Lo} = 0.015$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$ Equation D.2.6-1

$\eta = 1.7\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

```
%CALCULATION OF RUNUP USING TAW METHOD ACCORDING TO FEMA GUIDES AND SPECS

%created on 14 July 2007 by Dr. Kelly Legault on behalf of OCC


clear all

%--------------------------------------------------------------------------
% FILE INPUT
%--------------------------------------------------------------------------

%fname=input('what is the *.csv file? (use .csv extension and place single quotes
around the name)')
fname='KT-13.CSV'

 %     Read the first two columns into two variables:

  [sta,dep] = textread(fname,'%n%n%*[^\n]','delimiter',',');         %for non-
eroded profiles

%  [sta,dep] = textread(fname,'n%n','delimiter',',');                %for eroded
profiles


 %-------------------------------------------------------------------------
 %INPUT OCEANOGRAPHIC CONDITIONS
 %-------------------------------------------------------------------------


 %SWEL=input('what is the SWEL(ft)?    ')
 %SETUP=input('what is the SETUP(ft)?  ')

 %H0=input('what is the initial wave condition (ft)?  (either from Buoy or
ACES)    ');
 %T0=input('what is the wave period (s)?  (either deepwater (slope=0.035 or from
ACES)   ');

 SWEL=9.2
 H0=7.55
 T0=10.0
 SHORE=SWEL;



 %  FIND WAVELENGTH USING DEEPWATER DISPERSION RELATION
 %  using English units

 L0=32.15/(2*pi)*T0^2;

 %  Find Hb (Munk, 1949)
```

```
 Hb=H0/(3.3*(H0/L0)^(1/3));



%----------------------------------------------------------------------
% FINDING THE SURF ZONE DURING 100YR FLOOD + SETUP CONDITIONS
%-----------------------------------------------------------------------

% OFFSHORE

 %  Find the seaward extent of the surfzone

 Db=-Hb/.78+SHORE;
 BRK=find(dep<Db);

 if dep(1)>Db                   %if offshore station does not extend to depth of
breakers
    BRK=1;
 else
    BRK=find(dep<Db);
 end


 %----------------------------------------------------------------------


 %SWASH ZONE

 %  Find the shoreward extent of the surfzone

 SWL=find(dep<SHORE);

 SWL_0=SWL(end);                         % is the index of dep and sta at the
shoreline


 % THE NEXT LINES WILL FIND THE FIRST UPCROSSING OF THE SHORE IN THE SWASH ZONE --
THIS IS IMPORTANT IF AS CARDS
 % WERE USED FOR THE PROFILE IN WHAFIS

 SWL_del=diff(SWL);    % for bumps in the shoreline (when AS cards are specified)

 if SWL_del==1;
     SWL_0=SWL(end);
 else
     for j=1:length(SWL_del)
         if(SWL_del(j)>1)        %  to find the index of the first upcrossing with
SHORE -- specifies the inshore station
             SWL_0=j+1;
             break
         end
```

```
    end
end

clear j

%-------------------------------------------------------------------------
%STATIONS ACROSS THE SURF ZONE
%--------------------------------------------------------------------------

%  extract STATIONS between Db and SWL

 ind_sz=((BRK(end)):((SWL_0)))'  % to find the indices points within the surfzone

  sta_sz=sta(ind_sz(1:end));  %MAY NEED TO BE ADJUSTED TO ind_sz(2:end) if the end
of the sz is far beyond the breaker depth
  dep_sz=dep(ind_sz(1:end));  %or to (end+1) if the shoreline does not reach
SHORE / or (end-1) if extends beyond shore



 %------------------------------------------------------------------

%find average slope for the entire surfzone

slope_1=(dep_sz(end)-dep_sz(1))/(sta_sz(end)-sta_sz(1));

Hd=-1*(dep_sz-SHORE)*.78;                        %  defining wave heights


if Hd(1)>Hb;
    Hd(1)=Hb;                                    % ensuring that the most offshore
wave height is not greater than the breaking wave height
end

Irb(1)=(slope_1)/(sqrt(Hb/L0));                  %   initializing Irb
R_2(1)=Hb*1.77*Irb(1);                           %   initializing R_2
R_2_new=R_2(1);                                  %   initializing R_2_new
Irb_new=Irb(1);                                  %   initializing Irb_new
R_2_del=2;                                       %   initializing R_2_del
(difference between R_2 and R_2_new for initial while loop
slope_new=slope_1;                               %   initializing slope_new
j=1;                                             %   initializing j


%--------------------------------------------------------------------------
%APPLYING THE TAW METHOD ACROSS THE SURF ZONE
%--------------------------------------------------------------------------

for i=2:length(sta_sz)
```

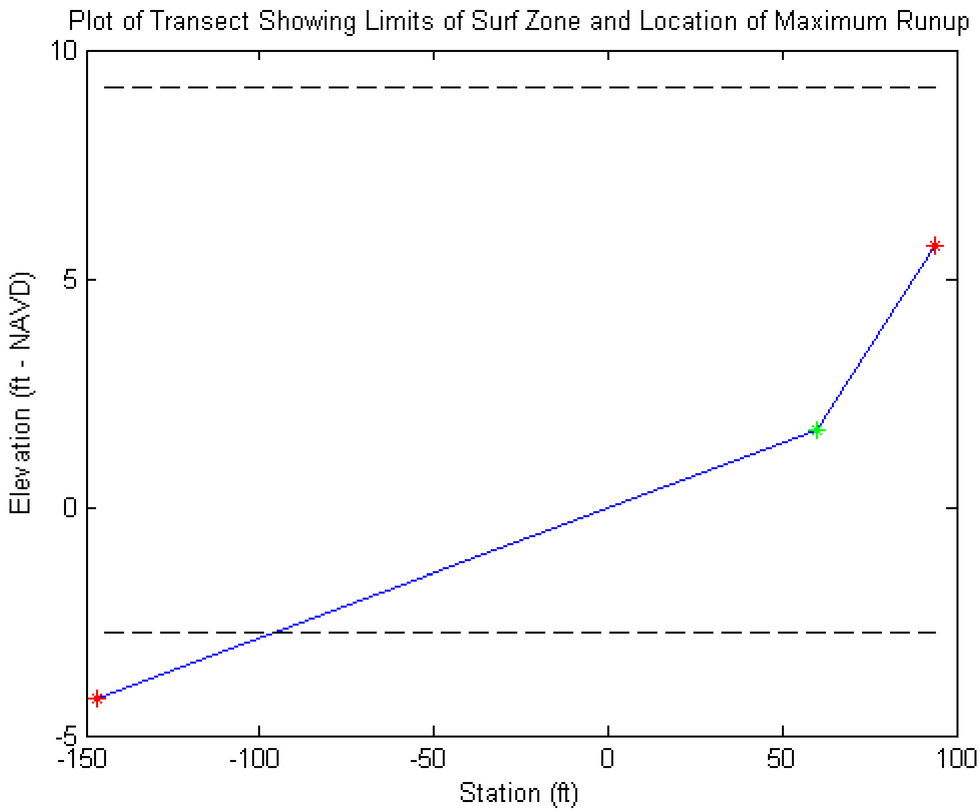
```
    %     'out of the loop'

    R_2(i)=R_2_new;
    slope(i-1)=slope_new;
    Irb(i)=Irb_new;
    R_2_del=2;                                  %re-initializing R_2_del

    i=j+1;




    if Irb(i)<1.8
        while(abs(R_2_del)>.001)
%              'in the loop 1'

            R_2(i)=R_2_new;
            slope(i)=(dep_sz(end)+R_2(i)-dep_sz(i))./((sta_sz(end)+((R_2(i)/slope
(end))))-sta_sz(i));           %calculating slope iterating for R_2 and slope

            R_2_new=Hd(i)*1.77*(slope(i)/(sqrt(Hd(i)/L0)));
%no reduction factor
            %                R_2_new=Hd(i)*0.6*1.77*Irb(i)
%adding a reduction factor
            Irb(i)=(slope(i)/(sqrt(Hd(i)/L0)));
%iterating for Irb
            R_2_del=abs(R_2(i)-R_2_new);
%convergence criterion
        end

        slope_new=slope(i);
        Irb_new=Irb(i);

                if Irb_new>1.8                  %if Irb_new coming from loop one
is greater than 1.8, it needs to be recalculated in loop two
                    j=i-1;
                else
                    j=i;
                end

    else if Irb(i)>1.8
            while(abs(R_2_del)>.001)
%                  'in the loop 2'
                R_2(i)=R_2_new;

                slope(i)=(dep_sz(end)+R_2(i)-dep_sz(i))./((sta_sz(end)+((R_2
(i)/slope(end))))-sta_sz(i));  %calculating slope iterating for R_2 and slope

                R_2_new=Hd(i)*(4.3-(1.6/(slope(i)/(sqrt(Hd
(i)/L0)))));                        %no reduction factor
                %                R_2_new=Hd(i)*0.6*(4.3-(1.6/(sqrt(Irb
```

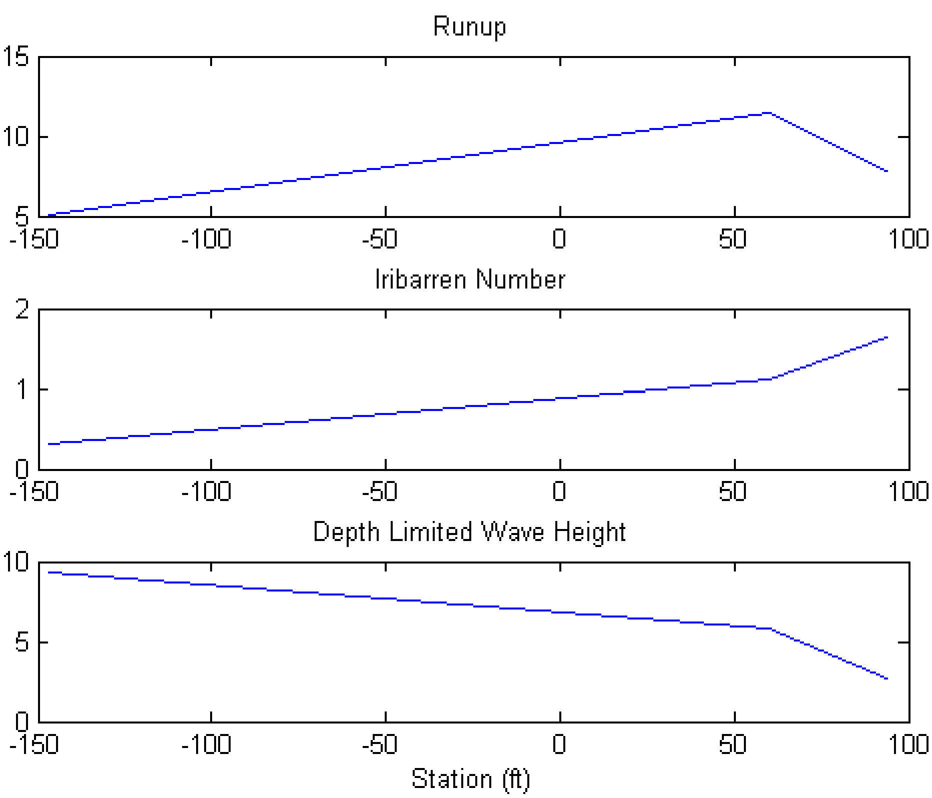
```
(i)))));              %adding reduction factor
                Irb(i)=(slope(i)/(sqrt(Hd
(i)/L0)));                                        %iterating for Irb
                R_2_del=abs(R_2(i)-
R_2_new);                                               %convergence criterion

            end

            slope_new=slope(i);
            Irb_new=Irb(i);

                if Irb_new<1.8                  %if Irb_new coming from loop two is
less than 1.8, it needs to be recalculated within loop one
                    j=i-1;
                else
                    j=i;
                end

        end
    end
end

%---------------------------------------------------------------------------
% END OF CONVERGENCE LOOPS AND CALCULATIONS OF IRB, R_2, SLOPE
%---------------------------------------------------------------------------
%lines 208-209 of code changed by Eileen Czarnecki 8/10/07 to find maximum
%of real part of R_2 (in the case of imaginary number at R_2(end)).

R_2_max=max(real(R_2))
ind=find(R_2==max(real(R_2)))
Hd_assoc_w_R_2_max=(Hd(ind))
Irb_assoc_w_R_2_max=(Irb(ind))

Critical_Depth_NAVD=dep_sz(ind)
Critical_Station_NAVD=sta_sz(ind)

Ds=Critical_Depth_NAVD-SHORE

for i=1:length(dep_sz)
    water_depth(i)=dep_sz(i)-SHORE;
end

%print out values of runup, wave height, Iribarren number, and water depth across
the surf
%zone

R_2

Hd

Irb
```

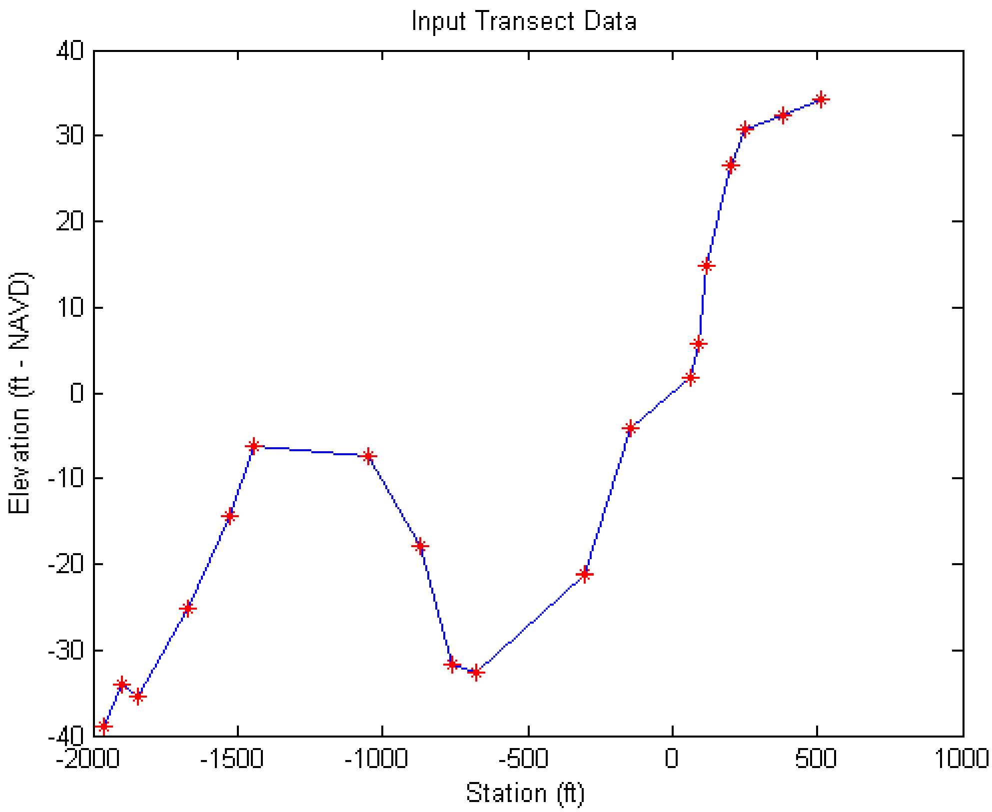
```
water_depth

%plotting
%figure 3 and axes labels added by Eileen Czarnecki 8/6/2007

figure
plot(sta_sz,dep_sz)
xlabel('Station (ft)')
ylabel('Elevation (ft - NAVD)')
hold on
plot(sta_sz,dep_sz,'r*')
plot(Critical_Station_NAVD, Critical_Depth_NAVD,'g*')
shore=ones(size(sta_sz))*SHORE;
plot(sta_sz,shore,'--k')
brk=ones(size(sta_sz))*Db;
plot(sta_sz,brk,'--k')
title('Plot of Transect Showing Limits of Surf Zone and Location of Maximum Runup')


figure
subplot(3,1,1)
plot(sta_sz,R_2)
title('Runup')
subplot(3,1,2)
plot(sta_sz,Irb)
title('Iribarren Number')
subplot(3,1,3)
plot(sta_sz,Hd)
title('Depth Limited Wave Height')
xlabel('Station (ft)')

figure
plot(sta,dep)
xlabel('Station (ft)')
ylabel('Elevation (ft - NAVD)')
title('Input Transect Data')
hold on
plot(sta,dep,'r*')


%________________________________________________________________________
%WARNING STATEMENT FOR VALIDITY RANGE OF TAW METHOD
%TAW IS VALID FOR IRRIBARREN NUMBER >= 0.5

%Added by Eileen Czarnecki on 8/6/2007
%________________________________________________________________________

if Irb_assoc_w_R_2_max<0.5
    warning('TAW runup methodology is not valid in this case.')
end
```

```
fname =

KT-13.CSV


SWEL =

    9.2000


H0 =

    7.5500


T0 =

    10


ind_sz =

    12
    13
    14


R_2_max =

   11.4676


ind =

     2


Hd_assoc_w_R_2_max =

    5.8460


Irb_assoc_w_R_2_max =

    1.1083


Critical_Depth_NAVD =

    1.7052
```

```
Critical_Station_NAVD =

    60


Ds =

   -7.4948


R_2 =

    5.0314   11.4676    7.7990


Hd =

    9.3279
    5.8460
    2.7035


Irb =

    0.3047    1.1083    1.6298


water_depth =

  -13.3822   -7.4948   -3.4661
```


Plot of Transect Showing Limits of Surf Zone and Location of Maximum Runup
Elevation (ft - NAVD)
Station (ft)
10
5
0
-5
-150
-100
-50
0
50
100


Runup
15
10
5
Iribarren Number
2
1
0
Depth Limited Wave Height
10
5
0
-150
-100
-50
0
50
100
Station (ft)



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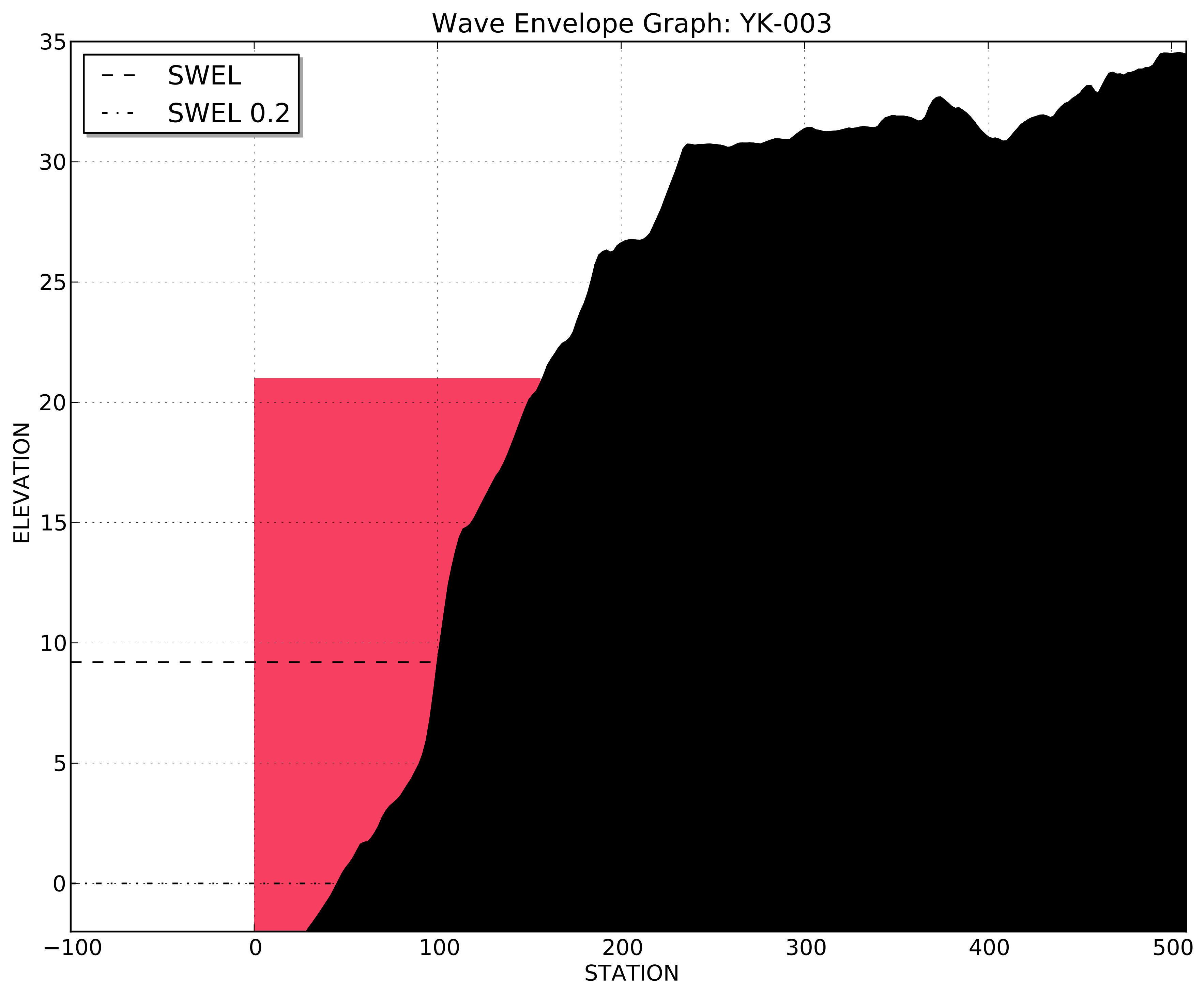
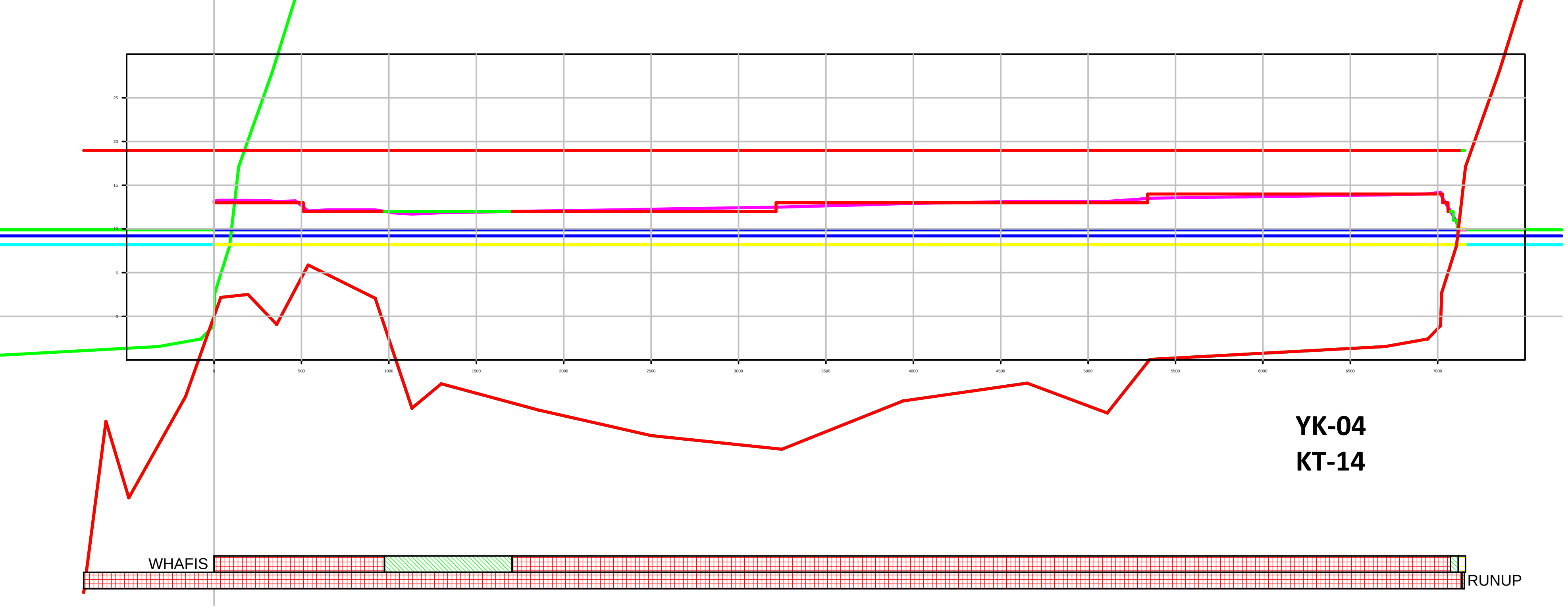

Wave Envelope Graph: YK-003
SWEL
SWEL 0.2
ELEVATION
STATION
35
30
25
20
15
10
5
0
−100
0
100
200
300
400
500


YK-04
KT-14
WHAFIS
RUNUP

Project: Fema Study- York County, ME
Group: KT-14 YK-04

Case: KT-14

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	1.41	MILES
Wind Direction (WDIR)	179.61	deg
Eq Neutral Wind Speed (Ue)	63.89	mph
Adjusted Wind Speed (Ua)	104.27	mph
Mean Wave Direction (THETA)	180.00	deg
Wave Height (Hmo)	3.49	feet
Wave Period (Tp)	3.38	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	129.61	0.05
2	139.61	0.07
3	149.61	0.20
4	159.61	0.22
5	169.61	0.71
6	179.61	1.81
7	189.61	0.79
8	199.61	0.62
9	209.61	0.46
10	219.61	0.38
11	229.61	0.31

Wave Growth: Deep

YK-04

Transect General Information - Transect ID: KT-14

Description | **Parameters**

Flooding Source	Spruce Creek		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	2.95		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM)
1% Deepwater Wave Period (sec)	7.9		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	0.7	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-14

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 3ft$ Deepwater significant wave height (determined from STWAVE)

$T := 7.9sec$ Peak wave period (determined from STWAVE)

$m := \frac{1}{12}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $Lo = 319.6\,ft$

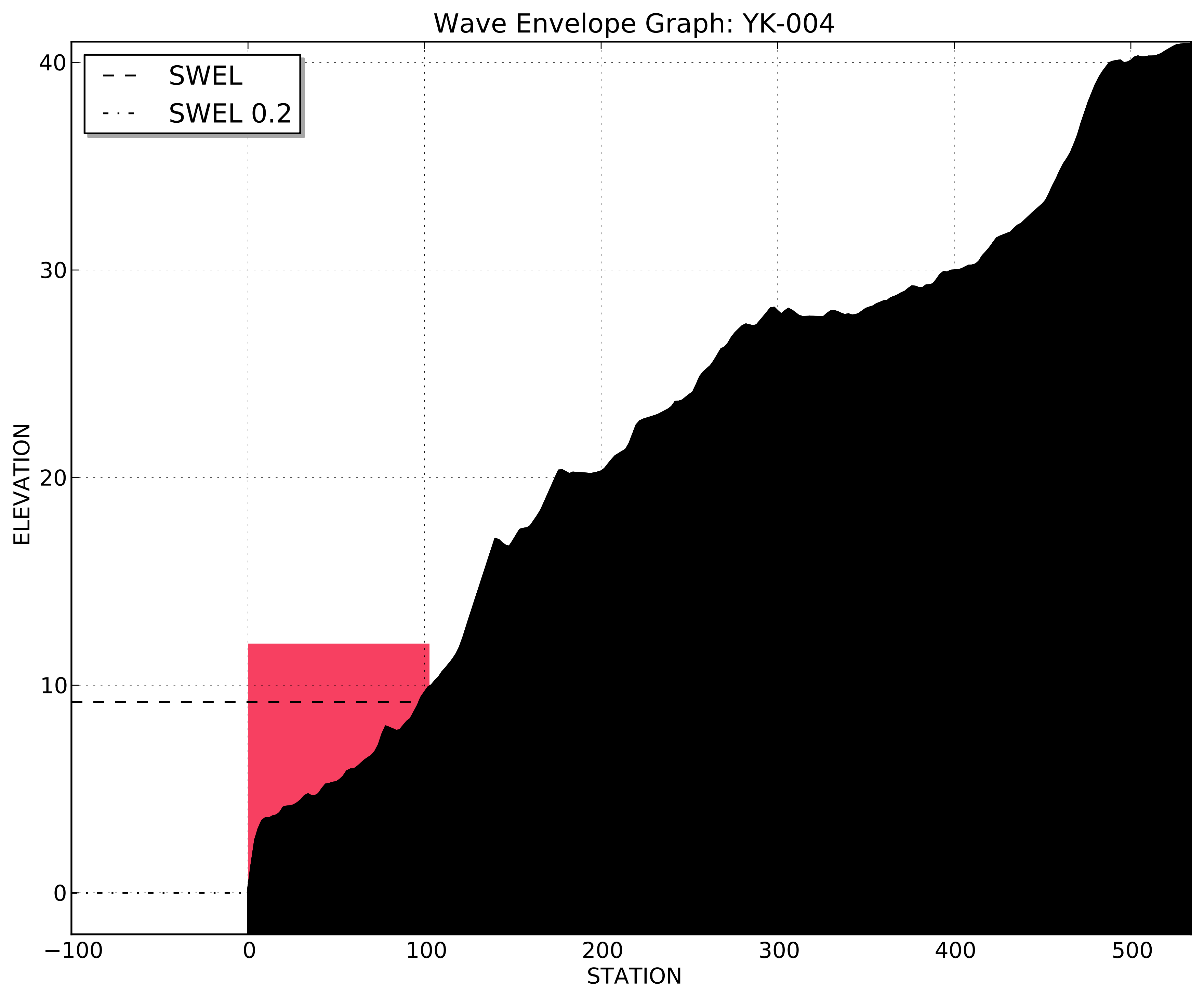
$\frac{Ho}{Lo} = 0.009$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

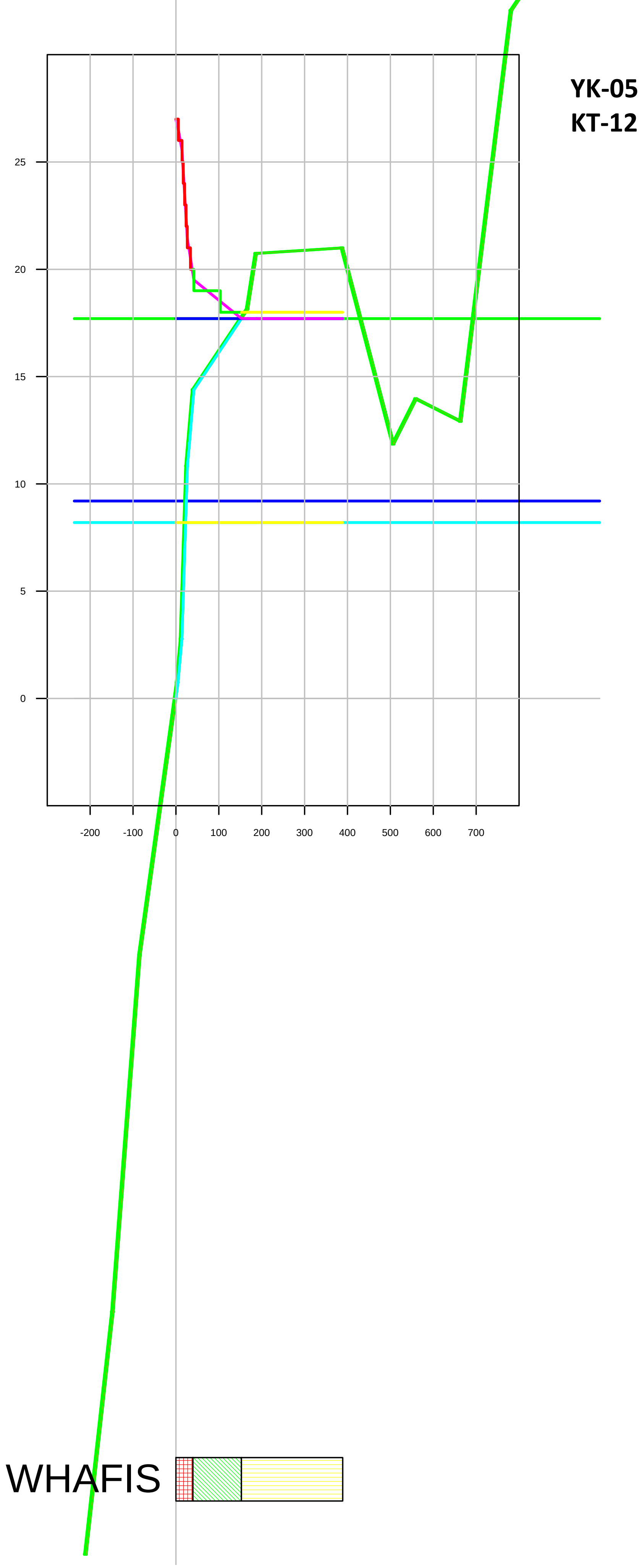
$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 0.7\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.



Wave Envelope Graph: YK-004
SWEL
SWEL 0.2
ELEVATION
STATION
40
30
20
10
0
−100
0
100
200
300
400
500



YK-05
KT-12
25
20
15
10
5
0
-200
-100
0
100
200
300
400
500
600
700
WHAFIS

Project: Fema Study- York County, ME
Group: KT-12 YK-05

Case: KT-12

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	23.04	MILES
Wind Direction (WDIR)	145.77	deg
Eq Neutral Wind Speed (Ue)	70.99	mph
Adjusted Wind Speed (Ua)	120.39	mph
Mean Wave Direction (THETA)	141.00	deg
Wave Height (Hmo)	8.72	feet
Wave Period (Tp)	5.63	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	95.77	1.07
2	105.77	1.03
3	115.77	1.00
4	125.77	1.22
5	135.77	24.00
6	145.77	24.00
7	155.77	0.54
8	165.77	0.56
9	175.77	0.53
10	185.77	0.48
11	195.77	0.41

Wave Growth: Deep

YK-05

Transect General Information - Transect ID: KT-12

Description | **Parameters**

Flooding Source	Portsmouth Harbor		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	8.5	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-12

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 29.9\,ft$ Deepwater significant wave height (determined from STWAVE)

$T := 11.4\,sec$ Wave Period (determined from STWAVE)

$m := \frac{1}{2}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $Lo = 665.5\,ft$

$\frac{Ho}{Lo} = 0.045$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$ Equation D.2.6-1

$\eta = 7.7\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

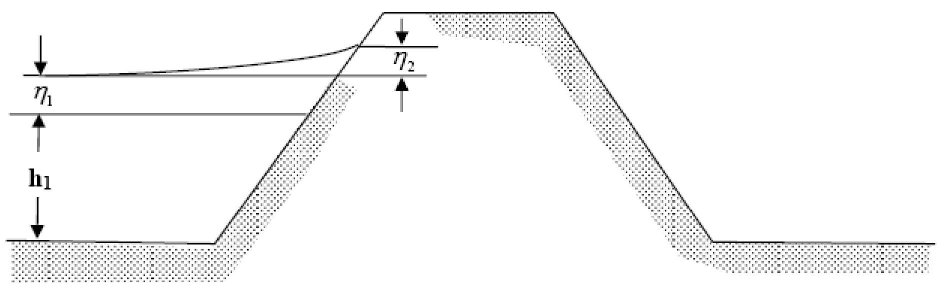


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-12 (Steep Slope)

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 7.7ft$ Wave setup without structure (From DIM MathCAD sheet for KT-12)

$h_1 := 8.5ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (From STWAVE)

$C := 14.4ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \dfrac{g \cdot T^2}{2 . \pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

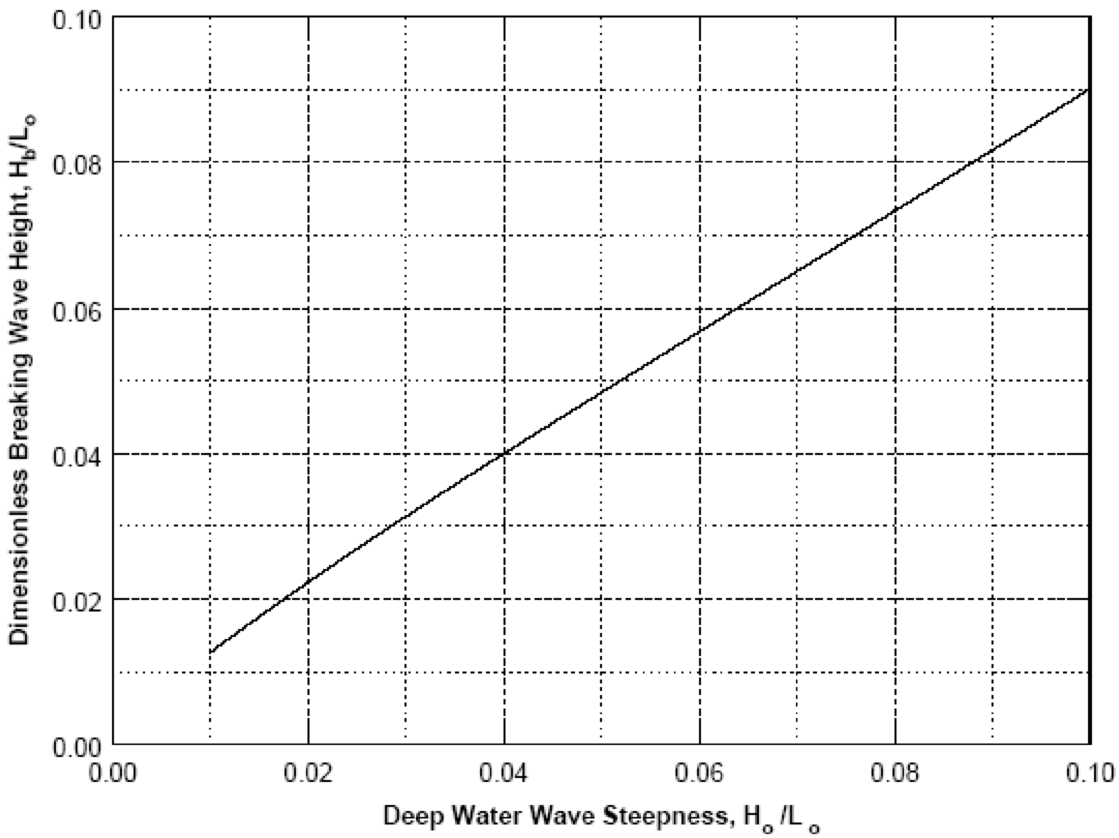


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

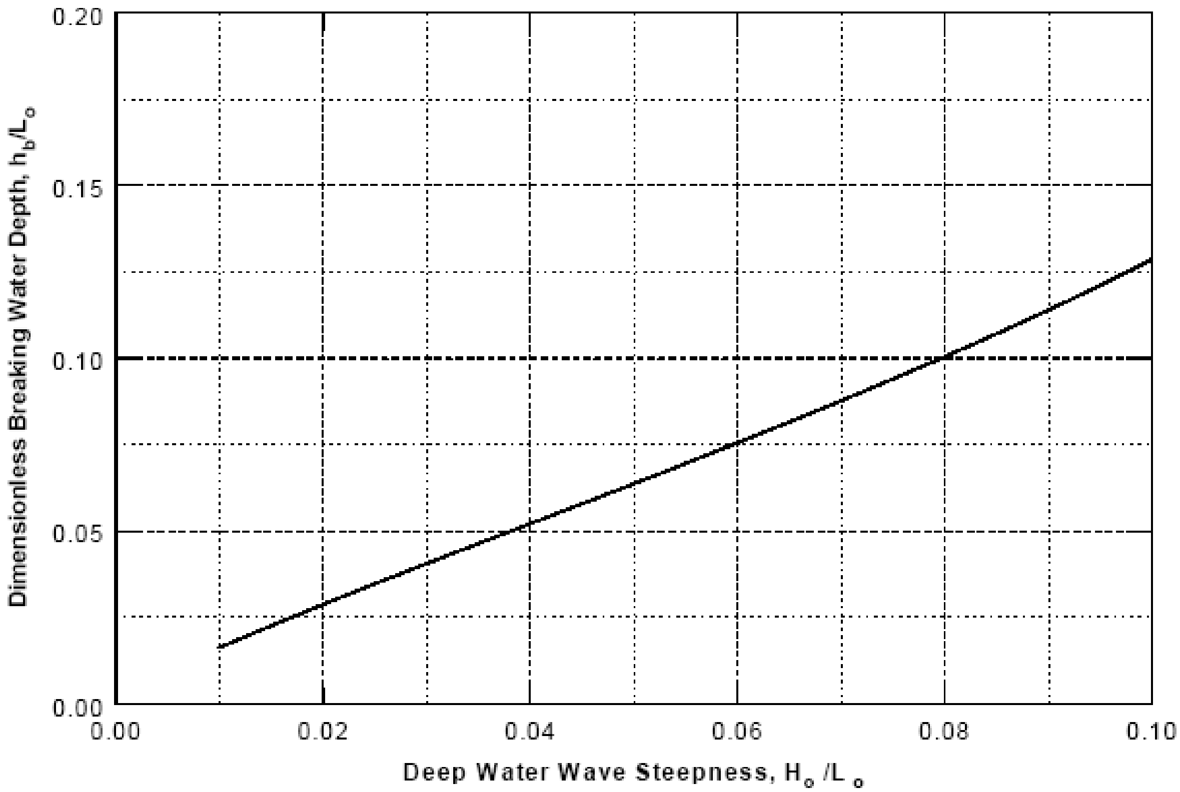


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d=h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,ft$

STEP 4: CALCULATE WAVE SETUP

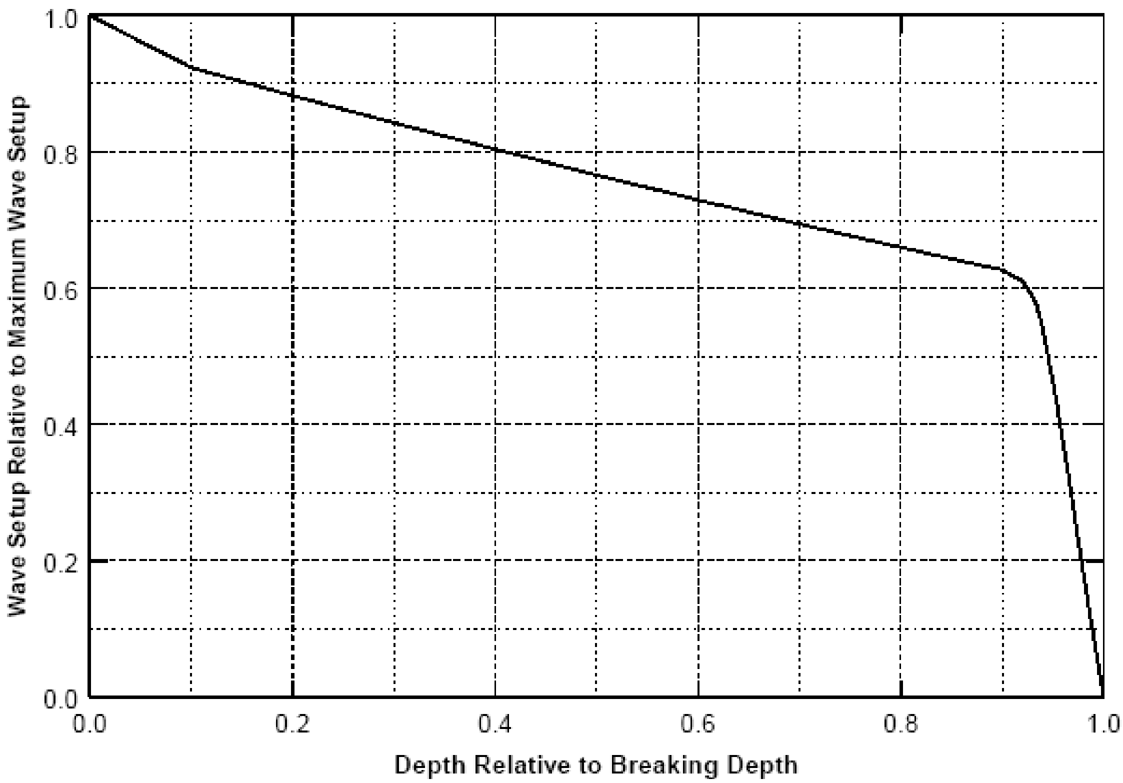


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$
R := \begin{cases}
\left[-0.8 \cdot \left(\frac{h_1}{h_b}\right) + 1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\
\left[-0.3919 \cdot \left(\frac{h_1}{h_b}\right) + 0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\
\left[-0.3475 \cdot \left(\frac{h_1}{h_b}\right) + 0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\
\left[-33.312 \cdot \left(\frac{h_1}{h_b}\right)^2 + 59.811 \cdot \left(\frac{h_1}{h_b}\right) - 26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\
\left[-9.8703 \cdot \left(\frac{h_1}{h_b}\right) + 9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1
\end{cases}
$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.22$ $\quad R = 0.87$

$\eta_1 := R \cdot \eta_{max}$ $\quad \eta_1 = 6.72\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\quad \eta_2 = 2.28\,ft$

Total Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 9\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$

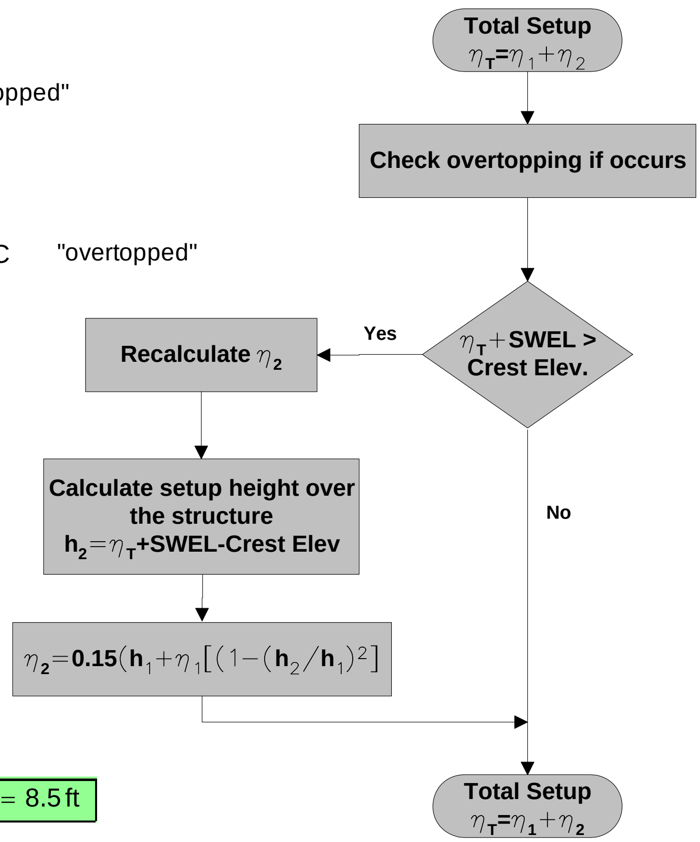
OVERTOPPED = "YES"

$h_2 = 3.8\,ft$

$\eta_1 = 6.72\,ft$

$\eta_2 = 1.83\,ft$

Total Final Wave Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 8.5\,ft$

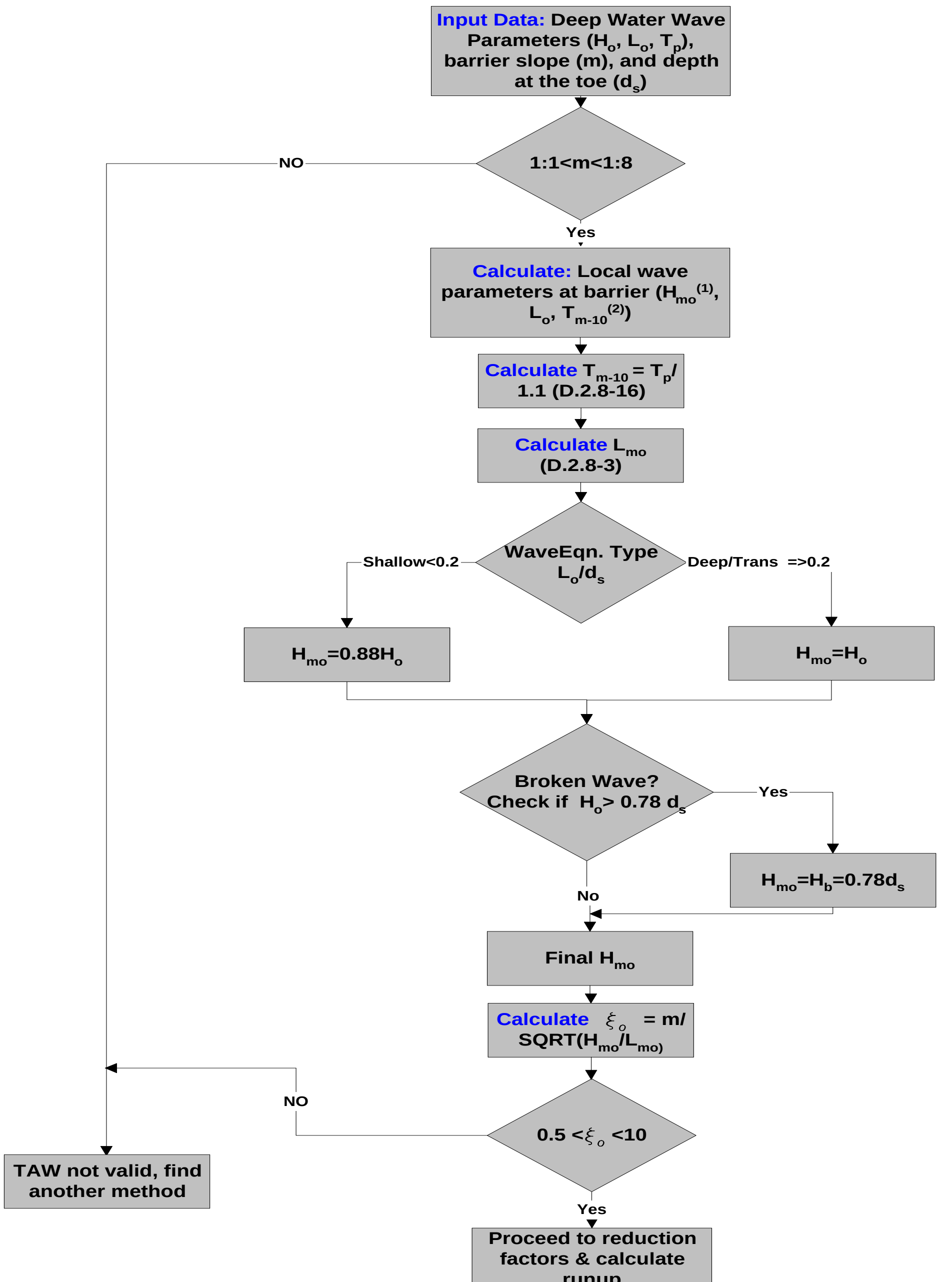


Flowchart for overtopping check

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE RUNUP ON BARRIERS ANALYSIS (TAW METHOD)

Wave runup is the uprush of water from wave action on a shore barrier intercepting still water level. The presence of coastal structures/steep slopes is not unusual. The structures could be overtopped or non overtopped.The following methodology (TAW) should be used for calculating wave runup on barriers.



Flowchart for TAW method to calculate runup on barrier

To use: *edit values highlighted in green*

Transect: KT-12

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$d_s := 8.45ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

indicate the available information **(T or S)**

○ Deep Water Wave Steepness $S := 0.035$ Deep water wave steepness ($S = \frac{H_o}{L_o}$) (Wave Steepness = 0.035 for extratropical storms "northeasters" and 0.040 for hurricanes)

◉ Peak Wave Period $T_p := 11.4sec$ Peak wave period (determined by STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (determined by STWAVE)

$C := 14.3ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet (NAVD)

$m := \frac{1}{2.7}$ Barrier slope

$$L_o := \begin{cases} \frac{H_o}{S} & \text{if } WS1 = 1 \\ \frac{g \cdot T_p^{\,2}}{2\pi} & \text{if } WS1 = 2 \\ 0 & \text{otherwise} \end{cases}$$

Deep Water Wave Length based on wave steepness input

Deep Water Wave Length based on peak wave period input

$$S := \begin{cases} S & \text{if } (WS1 = 1) \\ \frac{H_o}{L_o} & \text{if } (WS1 = 2) \\ 0 & \text{otherwise} \end{cases}$$

$$T_p := \begin{cases} \sqrt{\frac{L_o}{5.12 \cdot ft}} \cdot sec & \text{if } (WS1 = 1) \\ T_p & \text{if } (WS1 = 2) \\ 0 & \text{otherwise} \end{cases}$$

$S = 0.045$

$L_o = 665\,ft$

$T_p = 11.4 \cdot sec$

STEP 2: CALCULATE WAVE PARAMETERS AT BARRIER LOCATION

Check if broken wave

$$\text{BrokenWave} := \begin{cases} \text{"Broken"} & \text{if } H_o \ge 0.78 \cdot d_s \\ \text{"Not Broken"} & \text{if } H_o < 0.78 \cdot d_s \\ \text{"Undetermined"} & \text{otherwise} \end{cases}$$

H_b will be taken

$\text{BrokenWave} = \text{"Broken"}$

$$\text{WaveType} := \begin{cases} \text{"Shallow""} & \text{if } \frac{d_s}{L_o} < 0.2 \\ \text{"Transitional"} & \text{if } 0.2 \le \frac{d_s}{L_o} < 0.5 \\ \text{"Deep"} & \text{if } \left(\frac{d_s}{L_o}\right) \ge 0.5 \end{cases}$$

$\text{WaveType} = \text{"Shallow""}$

$$H_{mo} := \begin{cases} H_o & \text{if WaveType} = \text{"Deep"} \\ H_o & \text{if WaveType} = \text{"Transitional"} \\ ((.88 \cdot H_o)) & \text{if WaveType} = \text{"Shallow""} \\ \text{"NONE"} & \text{otherwise} \end{cases}$$

Deep Water

Shallow Water

$H_{mo} = 26.3\,\text{ft}$

$$H_{mo} := \begin{cases} d_s \cdot 0.78 & \text{if (BrokenWave} = \text{"Broken")} \\ H_{mo} & \text{if (BrokenWave} = \text{"Not Broken")} \\ 0 & \text{otherwise} \end{cases}$$

H_b will be taken

H_{mo} will be taken

in case error

$H_{mo} = 6.59\,\text{ft}$

$$T_{m10} := \frac{T_p}{1.1} \qquad \text{(D.2.8-16)}$$

$T_{m10} = 10.4\,\text{s}$

$$L_{mo} := \left(\frac{g}{2 \cdot \pi}\right) \cdot T_{m10}^{\;2} \qquad \text{(after D.2.8-3)}$$

$L_{mo} = 550\,\text{ft}$

Iribarren number, ξ_o

$$\xi_{om} := \frac{m}{\sqrt{\frac{H_{mo}}{L_{mo}}}}$$

$\xi_{om} = 3.38$

Check TAW method for Validity

TAW method will be valid if:

* 0.5< ξ_{om}<8–10

* 1:1<Barrier Slope<1:8

$$\text{TAW\_Validity} := \begin{cases} \text{"Valid"} & \text{if } \left[(0.5 < \xi_{om} < 10) \wedge (0.125 \le m \le 1)\right] \\ \text{"Not valid, Seek Another Method"} & \text{otherwise} \end{cases}$$

continue

TAW_Validity = "Valid"

STEP 3: CALCULATE REDUCTION FACTORS

In accordance to Table D.2.8-5

Roughness Reduction Factor,γ_r

- (●) Smooth concrete, asphalt, and smooth block revetment
- ( ) 1 Layer of Rock with Diameter, D. Hs/D=1 to 3
- ( ) 2 or more layers of rock Hs/D=1.5 to 6
- ( ) Quadratic Blocks

refer to CEM for accurate values

Wave Direction Factor,γ_β

$\gamma_{\beta d} := 0$ 0º for normally incident wave

- (●) Short-Crested Wave default
- ( ) Long-Crested Wave

Berm Section in Breakwater,γ_b

- (●) No Berm default
- ( ) Berm

Porosity Factor, γ_p

- ( ) P=0.1
- ( ) P=0.4
- (●) P=0.5 default
- ( ) P=0.6

other than defaults, refer to CEM for accurate values

Table D.2.8-5. Summary of γ Runup Reduction Factors

Runup Reduction Factor	Characteristic/Condition	Value of γ for Runup	
Roughness Reduction Factor, γ_r	Smooth Concrete, Asphalt, and Smooth Block Revetment	$\gamma_r = 1.0$	(D.2.8-10)
	1 Layer of Rock With Diameter, D. $H_s / D = 1$ to 3.	$\gamma_r = 0.55$ to 0.60	
	2 or More Layers of Rock. $H_s / D = 1.5$ to 6.	$\gamma_r = 0.5$ to 0.55	
	Quadratic Blocks	$\gamma_r = 0.70$ to 0.95. See Table V-5-3 in CEM for greater detail	
Berm Section in Breakwater, γ_b, B = Berm Width, $\left(\frac{\pi d_h}{x}\right)$ in radians	Berm Present in Structure Cross section. See Figure D.4.5-8 for Definitions of B, L_{berm} and Other Parameters	$\gamma_b = 1 - \frac{B}{2L_{berm}}\left[1+\cos\left(\frac{\pi d_h}{x}\right)\right], 0.6 < \gamma_B < 1.0$ $x = \begin{cases} R \; if \; \frac{-R}{H_{mo}} \le \frac{d_h}{H_{mo}} \le 0 \\ 2H_{mo} \; if \; 0 \le \frac{d_h}{H_{mo}} \le 2 \end{cases}$ (D.2.8-11) Minimum and maximum values of $\gamma_b = 0.6$ and 1.0, respectively	
Wave Direction Factor, γ_β, β is in degrees and = 0° for normally incident waves	Long-Crested Waves	$\gamma_\beta = \begin{cases} 1.0, 0 < \lvert\beta\rvert < 10^o \\ \cos(\lvert\beta\rvert - 10^o), 10^o < \lvert\beta\rvert < 63^o \\ 0.63, \lvert\beta\rvert > 63^o \end{cases}$ (D.2.8-12)	
	Short-Crested Waves	$1 - 0.0022\lvert\beta\rvert, \lvert\beta\rvert \le 80^o$ $1 - 0.0022\lvert 80\rvert, \lvert\beta\rvert \ge 80^o$ (D.2.8-13)	
Porosity Factor, γ_P	Permeable Structure Core	$\gamma_P = 1.0$, $\xi_{om} < 3.3$; $\gamma_P = \frac{2.0}{1.17(\xi_{om})^{0.46}}$, $\xi_{om} >$ 3.3 and porosity = 0.5. for smaller porosities, proportion γ_P according to porosity . See Figure D.2.8-7 for definition of porosity (D.2.8-14)	

Based on the seleced parameters, the reduction factors are summarized as follows:

Edit factors below if desired, otherwise leave as is:

Roughness Reduction Factor= $\gamma_r = 1$

Berm Section= $\gamma_b = 1$

Wave Direction Factor= $\gamma_\beta = 1$

Porosity Factor= $\gamma_p = 0.98$

$\gamma_r := \gamma_r$

$\gamma_b := \gamma_b$

$\gamma_\beta := \gamma_\beta$

$\gamma_p := \gamma_p$

STEP 4: CALCULATE RUNUP

$$R := \begin{cases} H_{mo}\cdot\left(1.77\cdot\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\xi_{om}\right) & \text{if } 0.5 \le \gamma_b\cdot\xi_{om} < 1.8 \\ H_{mo}\cdot\left[\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\left(4.3 - \dfrac{1.6}{\sqrt{\xi_{om}}}\right)\right] & \text{if } 1.8 \le \gamma_b\cdot\xi_{om} \\ 0 & \text{otherwise} \end{cases}$$

Total Final Wave Runup

$R = 22.1\,\text{ft}$

Check Overtopping

$$\text{OVERTOPPED} := \begin{cases} \text{"YES"} & \text{if } (R + \text{SWEL}) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

OVERTOPPED = "YES"

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007

$$\gamma_b := \begin{cases} 1 & \text{if } BSB = 1 \\ 0.6 & \text{if } BSB = 2 \end{cases}$$

$$\gamma_\beta := \begin{cases} (1 - 0.0022\gamma_{\beta d}) & \text{if } (|\gamma_{\beta d}| < 80) \wedge WDF \\ (1 - 0.0022 \cdot |80|) & \text{if } (80 \le |\gamma_{\beta d}| \le 90) \wedge WDF = 1 \\ 1 & \text{if } [(0 \le |\gamma_{\beta d}|) \le 10 \wedge WDF = 2] \\ \cos(|\gamma_{\beta d}| - 10) & \text{if } [(10 < |\gamma_{\beta d}| \le 63) \wedge WDF = 2] \\ 0.63 & \text{if } (|\gamma_{\beta d}| > 63) \wedge WDF = 2 \\ 0 & \text{otherwise} \end{cases}$$

$$\gamma_r := \begin{cases} 1 & \text{if } RRF = 1 \\ 0.58 & \text{if } RRF = 2 \\ 0.53 & \text{if } RRF = 3 \\ 0.70 & \text{if } RRF = 4 \\ 0 & \text{otherwise} \end{cases}$$

$$\gamma_p := \begin{cases} 1 & \text{if } (PF = 3) \wedge \xi_{om} \le 3.3 \\ \left(\left(\dfrac{2}{1.17 \cdot \xi_{om}^{0.46}}\right)\right) & \text{if } (PF = 3) \wedge \xi_{om} > 3.3 \\ 0.5 & \text{otherwise} \end{cases}$$

SaveDataWS1(data, Get_or_Save) := 2

(data Get_or_Save)

SaveDataRRF(data, Get_or_Save) := 1

(data Get_or_Save)

SaveDataWDF(data, Get_or_Save) := 1

(data Get_or_Save)

SaveDataBSB(data, Get_or_Save) := 1

(data Get_or_Save)

SaveDataPF(data, Get_or_Save) := 3

(data Get_or_Save)

$\text{SaveDataRRF}(\text{RRF}, \text{"Save"}) = 1$

$\text{RRF} = 1$

$\text{SaveDataWDF}(\text{WDF}, \text{"Save"}) = 1$

$\text{WDF} = 1$

$\text{SaveDataBSB}(\text{BSB}, \text{"Save"}) = 1$

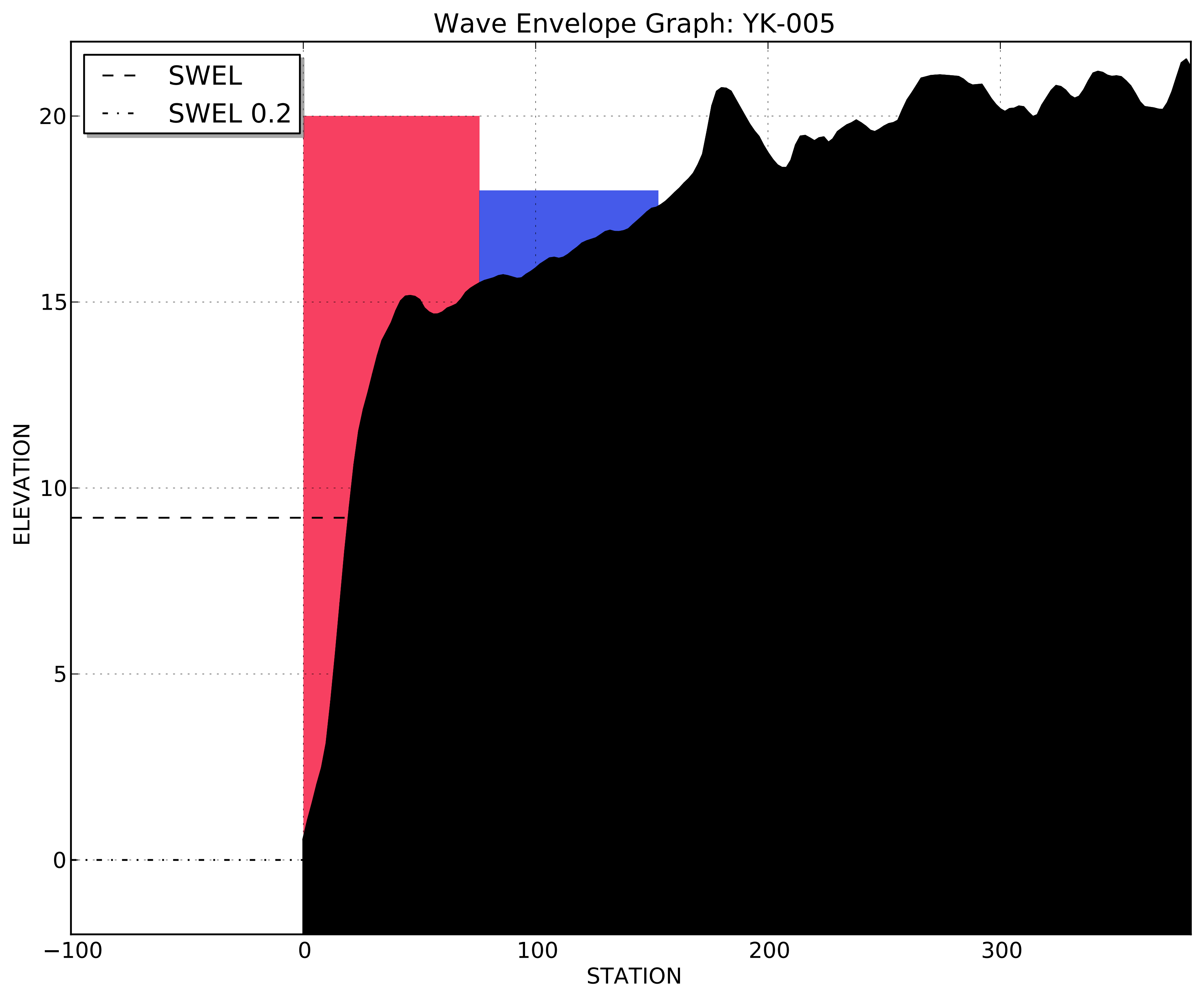
$\text{BSB} = 1$

$\text{SaveDataWS1}(\text{WS1}, \text{"Save"}) = 2$

$\text{WS1} = 2$

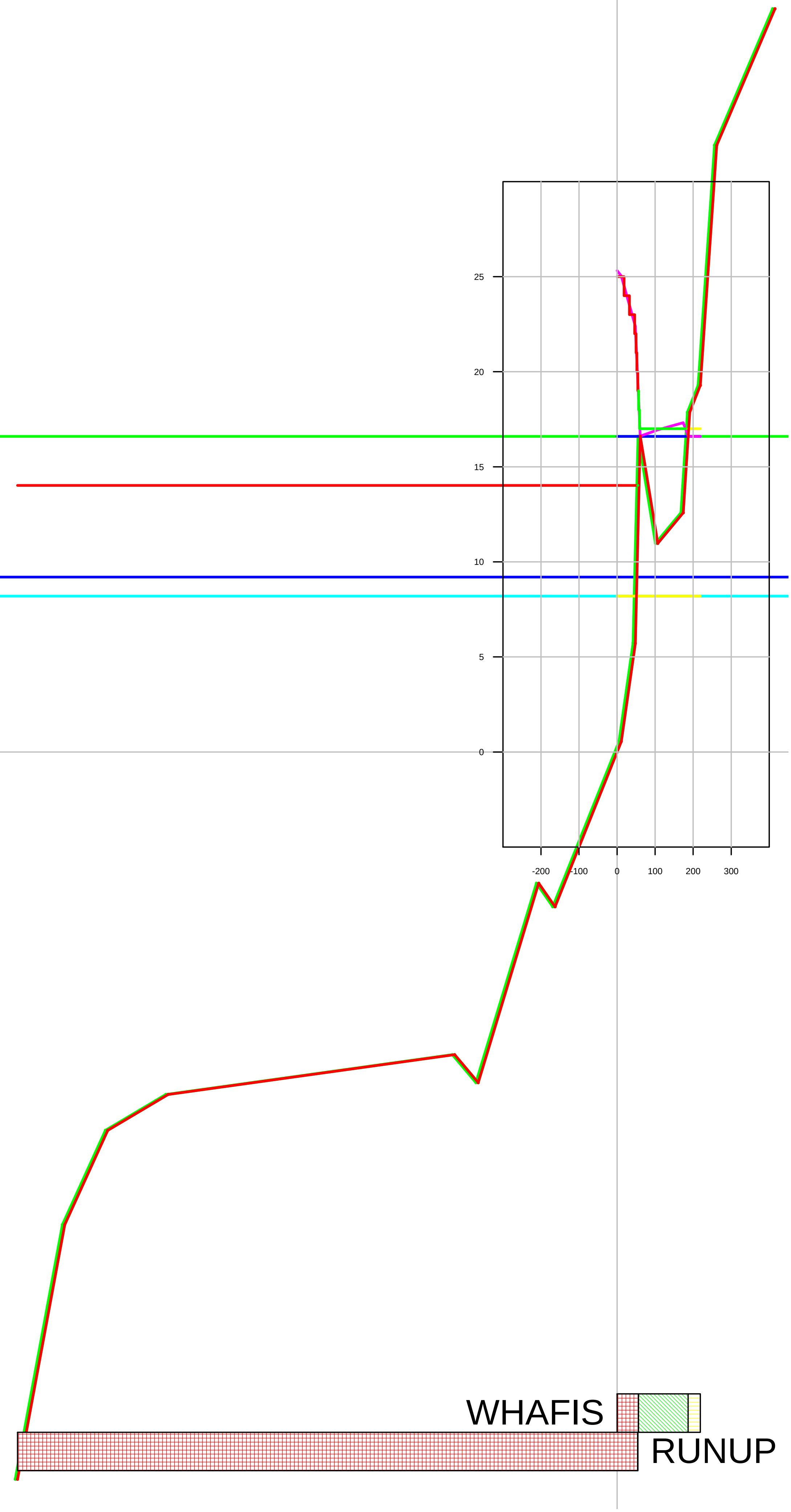
$\text{SaveDataPF}(\text{PF}, \text{"Save"}) = 3$

$\text{PF} = 3$



Wave Envelope Graph: YK-005
SWEL
SWEL 0.2
20
15
10
5
0
−100
0
100
200
300
ELEVATION
STATION

YK-06
KT-11
Intact



Project: Fema Study- York County, ME
Group: KT-11 YK-06

Case: KT-11

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	23.81	MILES
Wind Direction (WDIR)	186.84	deg
Eq Neutral Wind Speed (Ue)	70.99	mph
Adjusted Wind Speed (Ua)	120.39	mph
Mean Wave Direction (THETA)	171.00	deg
Wave Height (Hmo)	8.32	feet
Wave Period (Tp)	5.51	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	136.84	0.75
2	146.84	0.84
3	156.84	24.00
4	166.84	24.00
5	176.84	24.00
6	186.84	2.68
7	196.84	0.76
8	206.84	0.86
9	216.84	0.84
10	226.84	0.98
11	236.84	1.21

Wave Growth: Deep

YK-06 Failed

Transect General Information - Transect ID: KT-11_1

Description | **Parameters**

Flooding Source: Pepperell Cove

10% chance SWEL(ft)	8.2	Source	USACENew England Tidal Profi
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	7.4	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

YK-06 Intact

Transect General Information - Transect ID: KT-11_F

Description | **Parameters**

Flooding Source	Pepperell Cove		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	7.4	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-11

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 29.9\,ft$ Deepwater significant wave height (determined from STWAVE)

$T := 11.4\,sec$ Peak wave period (determined from STWAVE)

$m := \frac{1}{5}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2 \cdot \pi}$ Deep water wave length $Lo = 665.5\,ft$

$\frac{Ho}{Lo} = 0.045$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 6.4\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

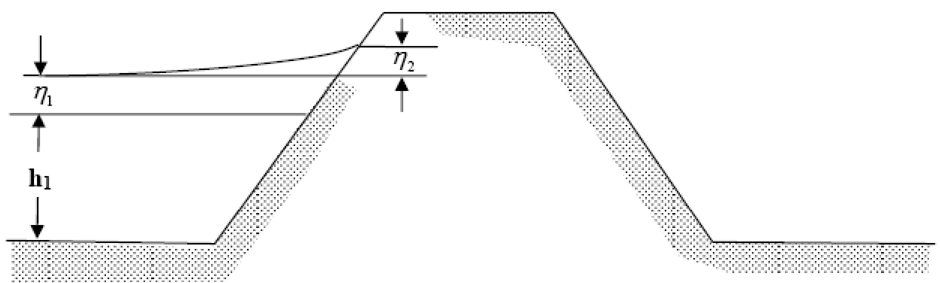


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-11_I

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 6.4ft$ Wave setup without structure (From DIM MathCAD sheet for KT-11)

$h_1 := 3.48ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (From STWAVE)

$C := 16.6ft$ Crest of the structure/slope Elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

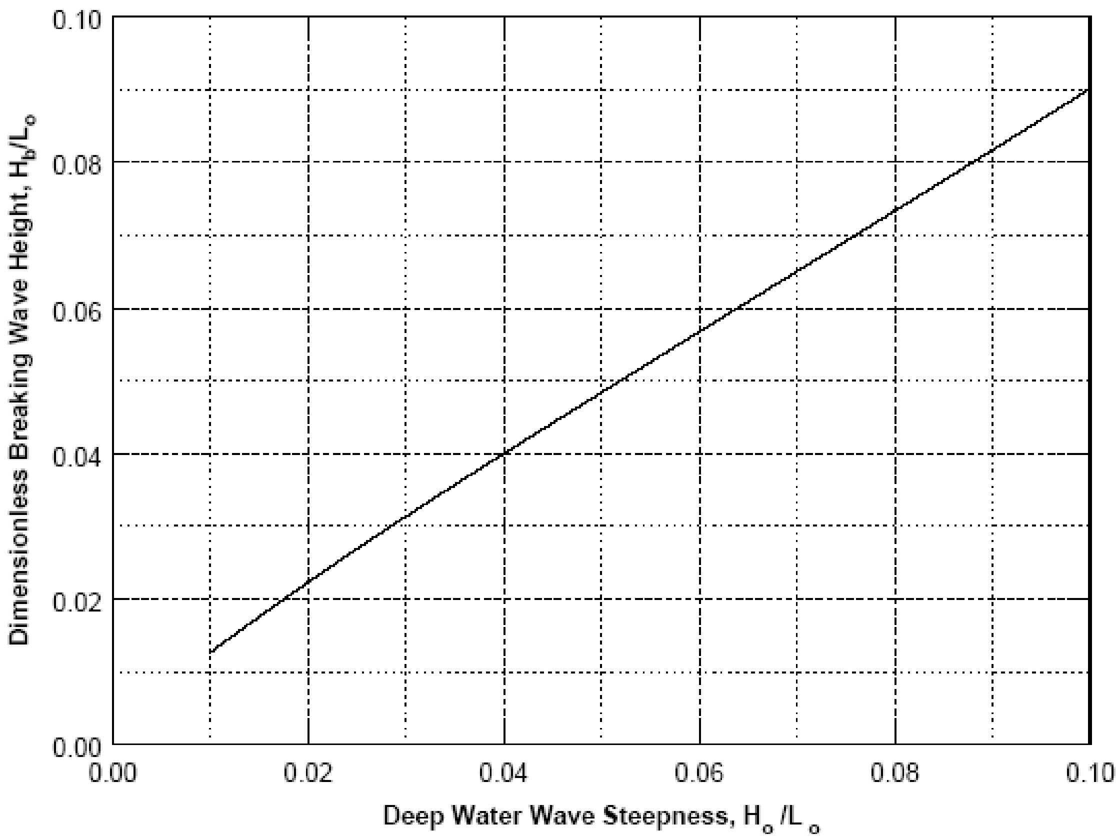


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

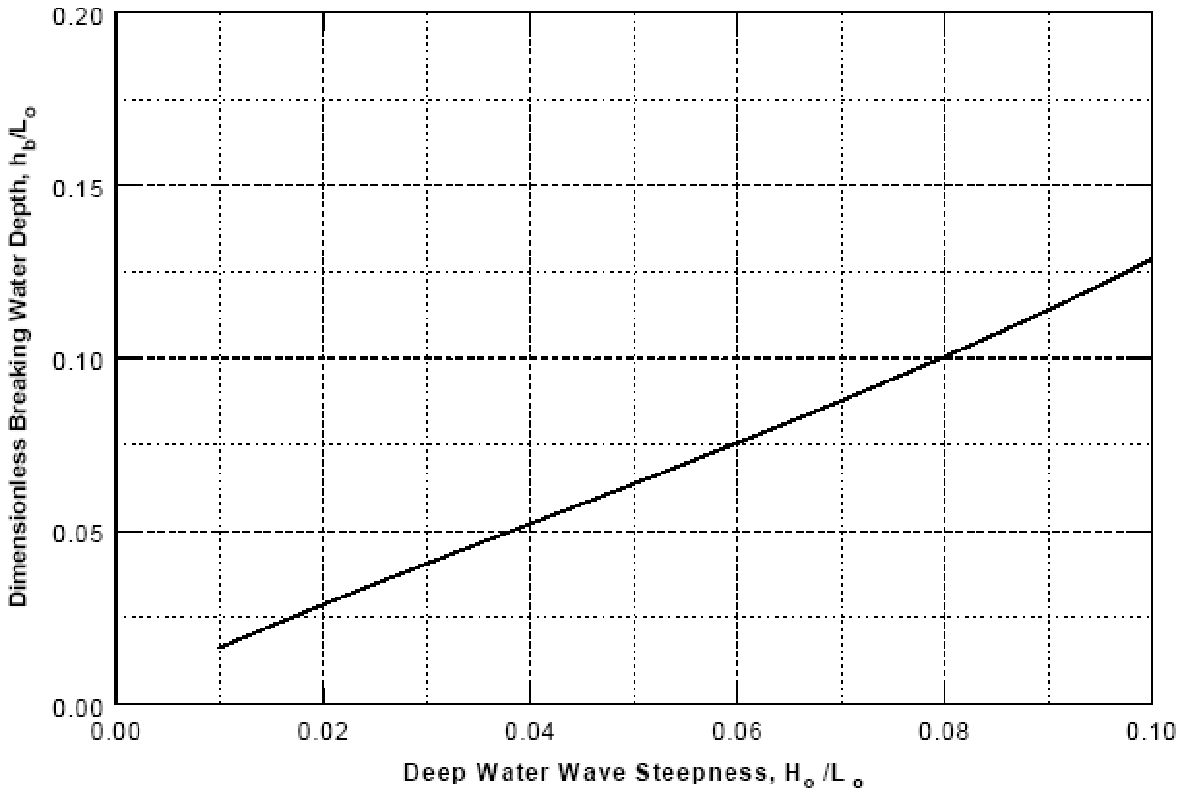


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d = h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,ft$

STEP 4: CALCULATE WAVE SETUP

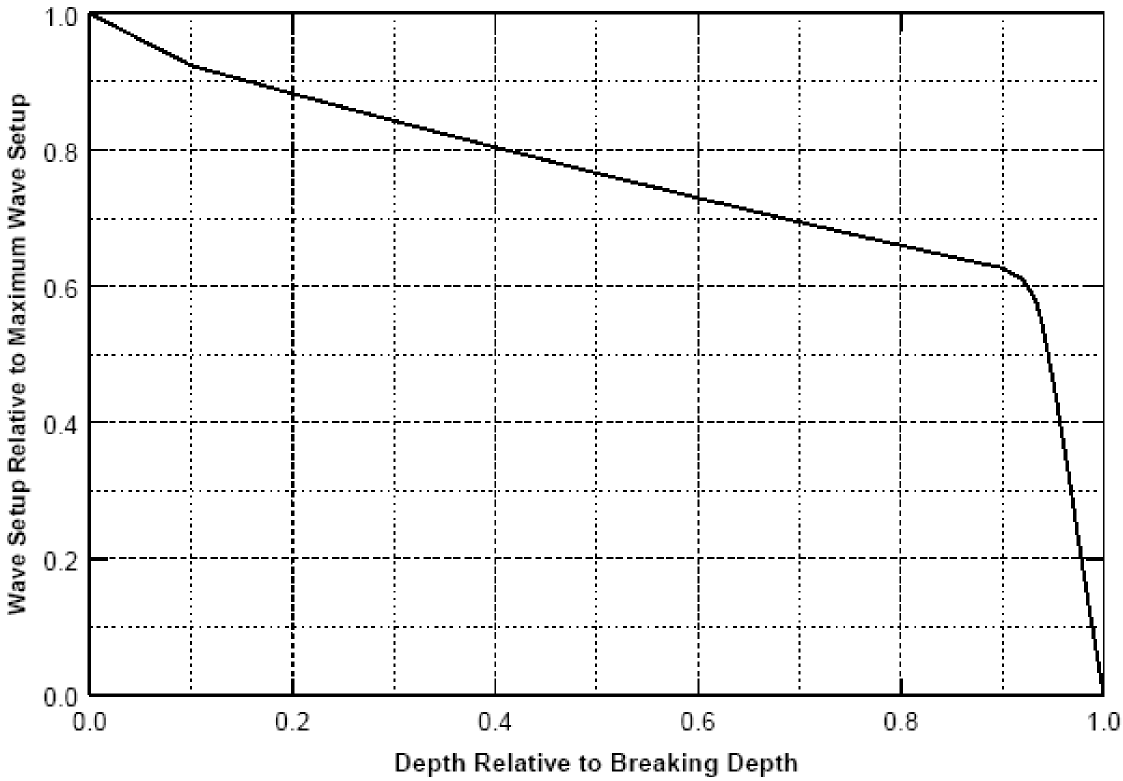


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$R := \begin{cases} \left[-0.8\cdot\left(\frac{h_1}{h_b}\right) + 1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\ \left[-0.3919\cdot\left(\frac{h_1}{h_b}\right) + 0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\ \left[-0.3475\cdot\left(\frac{h_1}{h_b}\right) + 0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\ \left[-33.312\cdot\left(\frac{h_1}{h_b}\right)^2 + 59.811\cdot\left(\frac{h_1}{h_b}\right) - 26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\ \left[-9.8703\cdot\left(\frac{h_1}{h_b}\right) + 9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1 \end{cases}$$

Estimated curve equation in figure D.2.6-9

For $\dfrac{h_1}{h_b} = 0.09$ $\qquad R = 0.93$

$\eta_1 := R \cdot \eta_{max}$ $\qquad \eta_1 = 5.94\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\qquad \eta_2 = 1.41\,ft$

Total Setup $\qquad \eta_T := \eta_1 + \eta_2$ $\qquad \eta_T = 7.4\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\dfrac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$

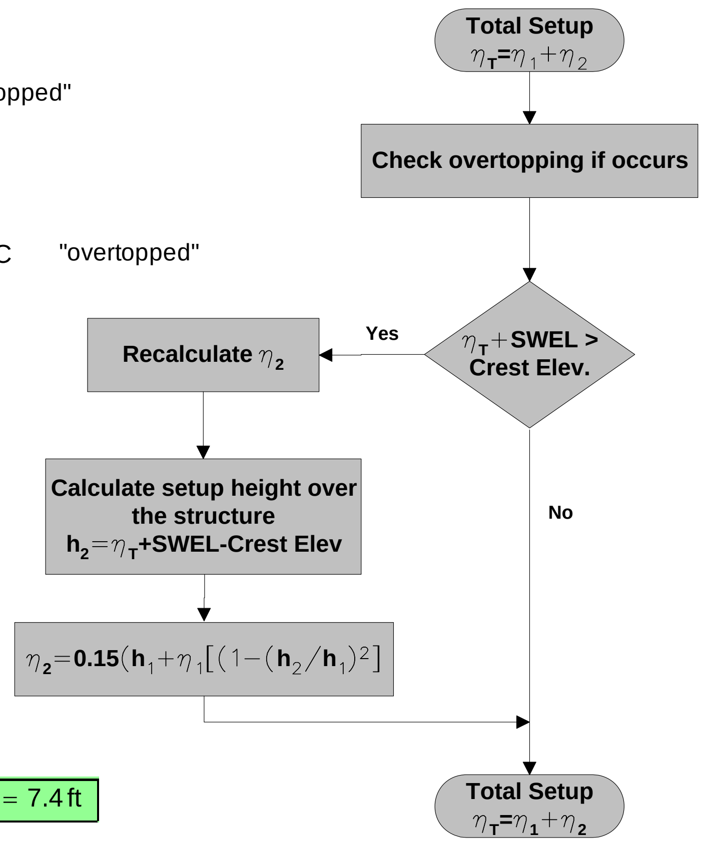
$OVERTOPPED = \text{"NO"}$

$h_2 = 0\,ft$

$\eta_1 = 5.94\,ft$

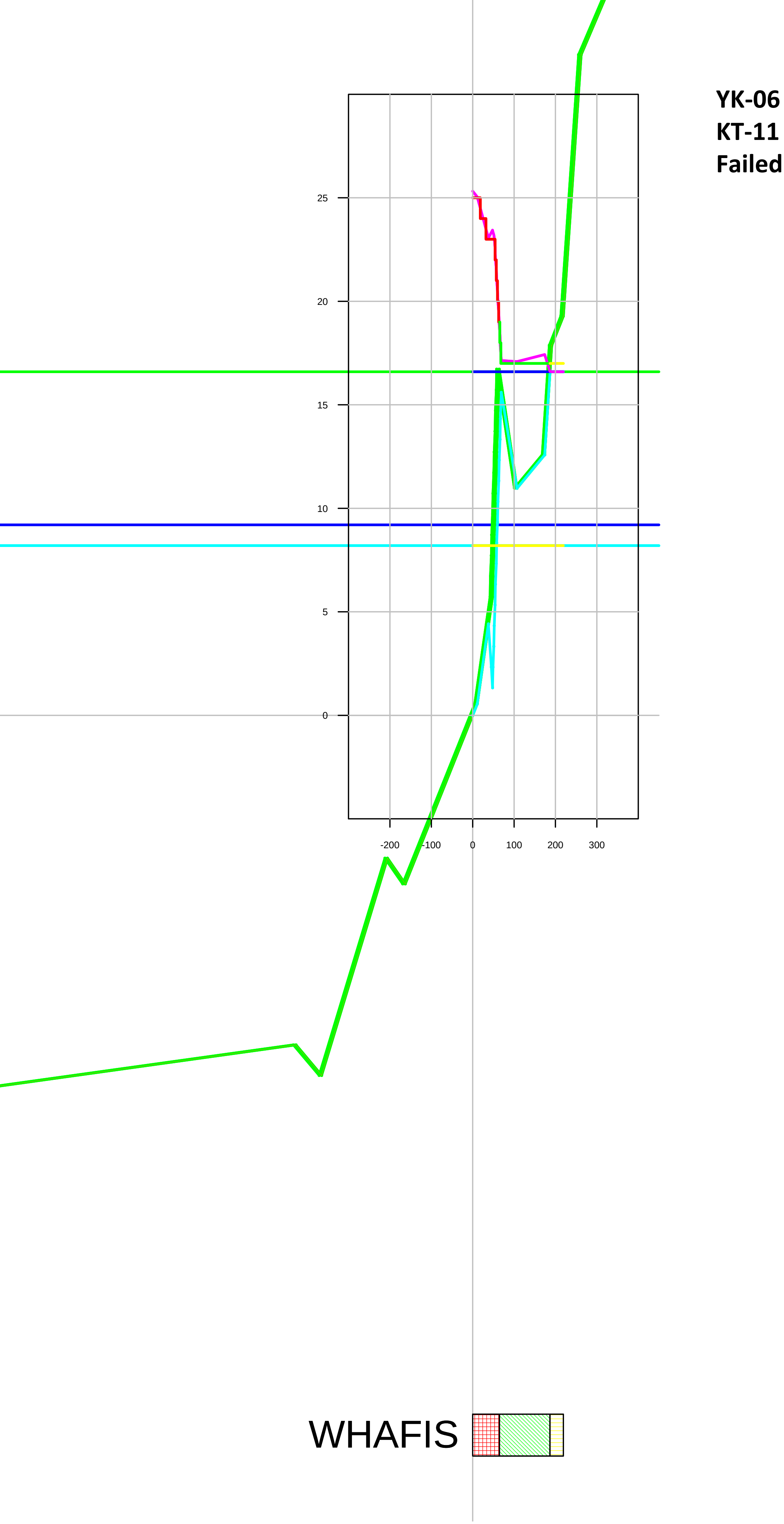
$\eta_2 = 1.41\,ft$

Total Final Wave Setup $\qquad \eta_T := \eta_1 + \eta_2$ $\qquad \boxed{\eta_T = 7.4\,ft}$



Flowchart for overtopping check

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.



YK-06
KT-11
Failed
25
20
15
10
5
0
-200
-100
0
100
200
300
WHAFIS

Project: Fema Study- York County, ME
Group: KT-10 YK-07

Case: KT-10 YK-07

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	15.76	MILES
Wind Direction (WDIR)	181.58	deg
Eq Neutral Wind Speed (Ue)	70.99	mph
Adjusted Wind Speed (Ua)	120.39	mph
Mean Wave Direction (THETA)	182.00	deg
Wave Height (Hmo)	8.77	feet
Wave Period (Tp)	5.65	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	131.58	0.08
2	141.58	0.09
3	151.58	0.12
4	161.58	0.75
5	171.58	1.28
6	181.58	24.00
7	191.58	2.73
8	201.58	1.73
9	211.58	0.86
10	221.58	0.99
11	231.58	1.03

Wave Growth: **Deep**

YK-07

Transect General Information - Transect ID: KT-10

Description | **Parameters**

Flooding Source	Pepperell Cove		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	7.9	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDDF		1% WINDIF	
0.2 % WINDDF		0.2% WINDIF	

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

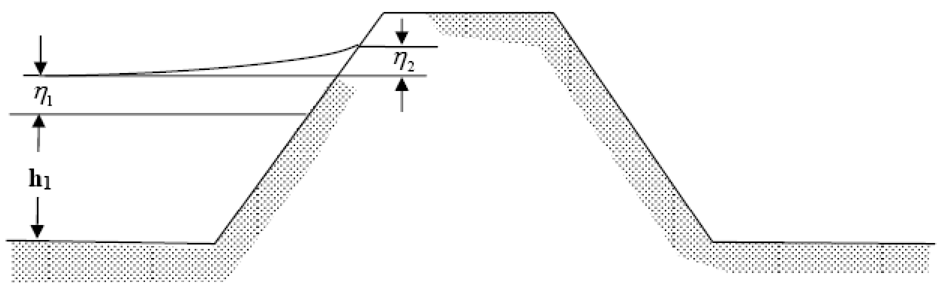


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-11_F

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 6.4ft$ Wave setup without structure (From DIM MathCAD sheet for KT-11)

$h_1 := 3.48ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (from STWAVE)

$C := 16.6ft$ Crest of the structure/slope Elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \dfrac{g \cdot T^2}{2.\pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

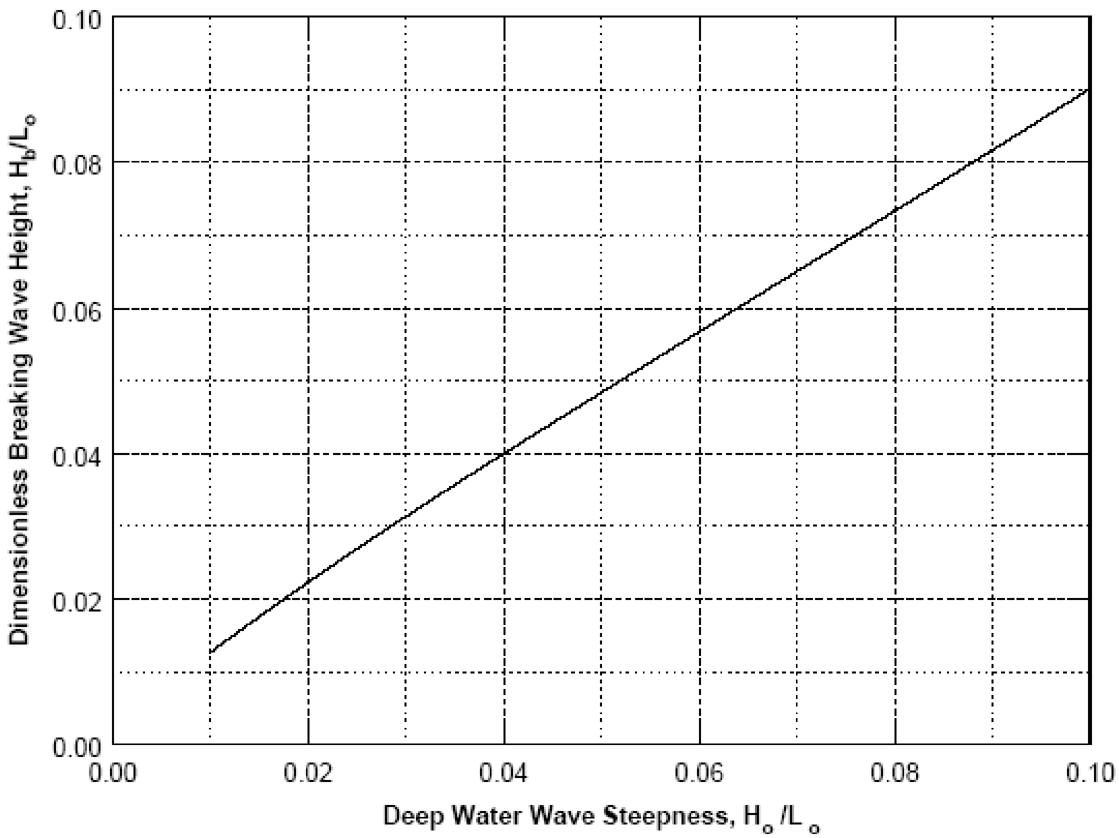


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

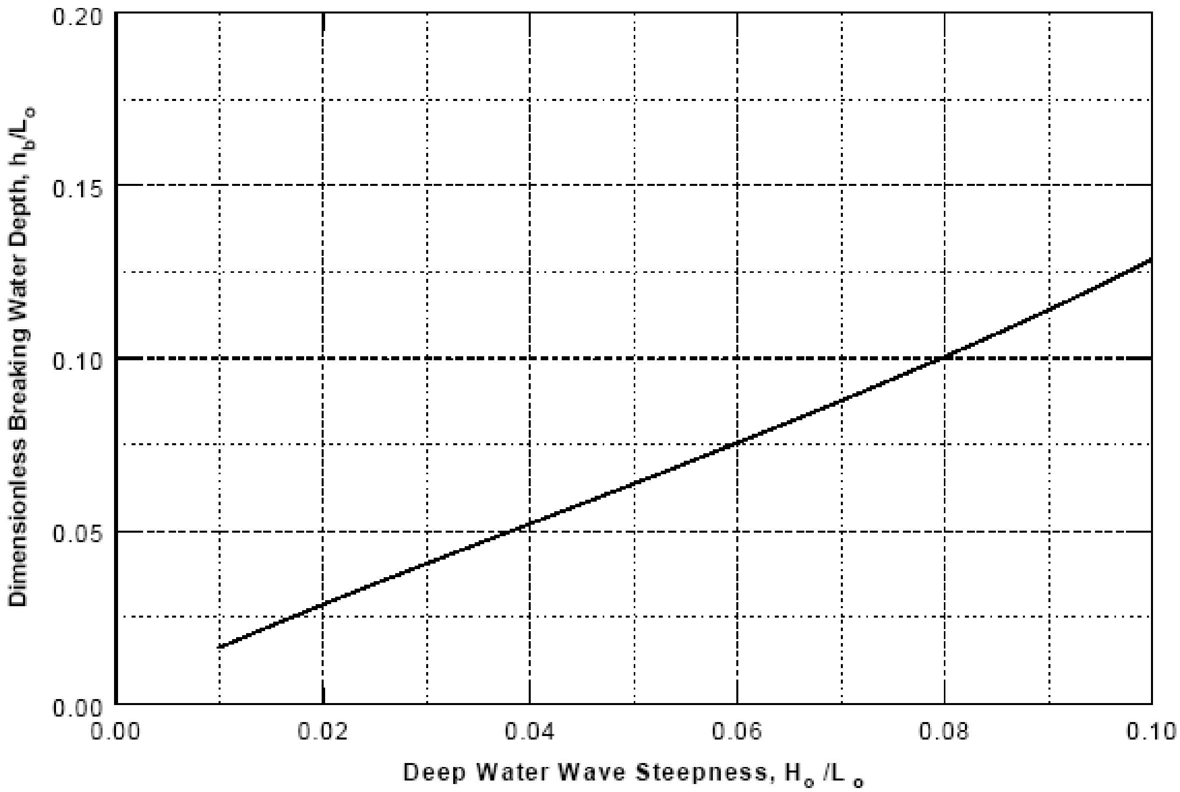


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d = h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,\text{ft}$

STEP 4: CALCULATE WAVE SETUP

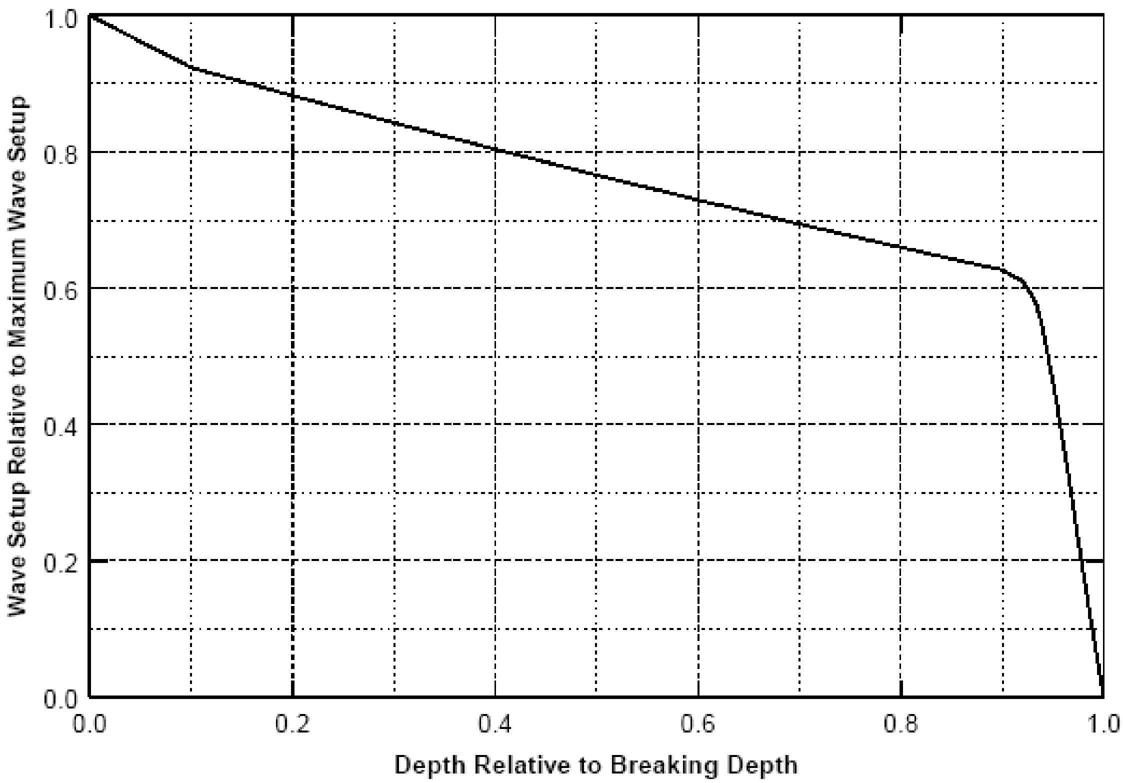


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$R := \begin{cases} \left[-0.8 \cdot \left(\frac{h_1}{h_b}\right) + 1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\ \left[-0.3919 \cdot \left(\frac{h_1}{h_b}\right) + 0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\ \left[-0.3475 \cdot \left(\frac{h_1}{h_b}\right) + 0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\ \left[-33.312 \cdot \left(\frac{h_1}{h_b}\right)^2 + 59.811 \cdot \left(\frac{h_1}{h_b}\right) - 26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\ \left[-9.8703 \cdot \left(\frac{h_1}{h_b}\right) + 9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1 \end{cases}$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.09$ $\quad R = 0.93$

$\eta_1 := R \cdot \eta_{max}$ $\quad \eta_1 = 5.94\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\quad \eta_2 = 1.41\,ft$

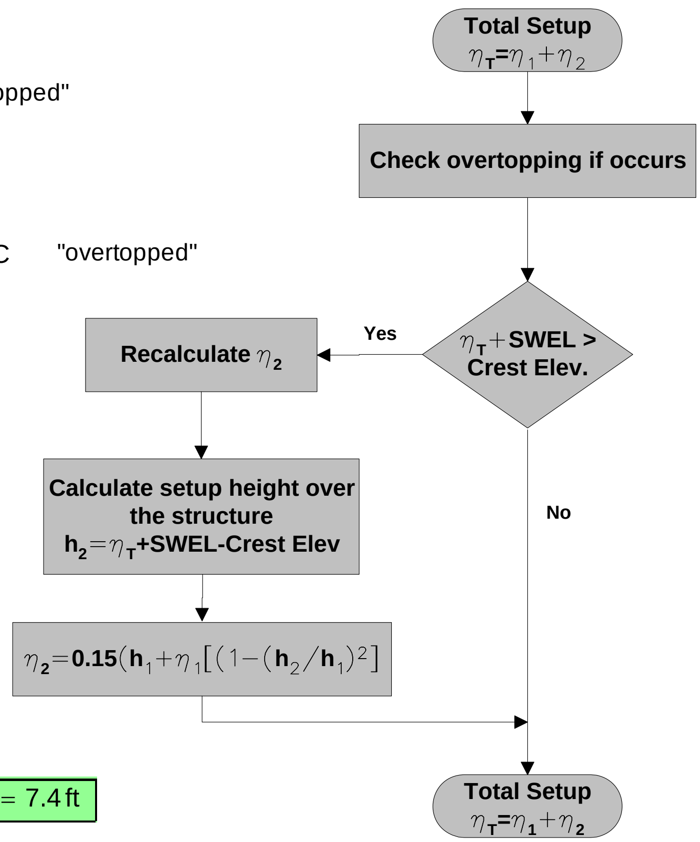
Total Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 7.4\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$



$OVERTOPPED = \text{"NO"}$

$h_2 = 0\,ft$

$\eta_1 = 5.94\,ft$

$\eta_2 = 1.41\,ft$

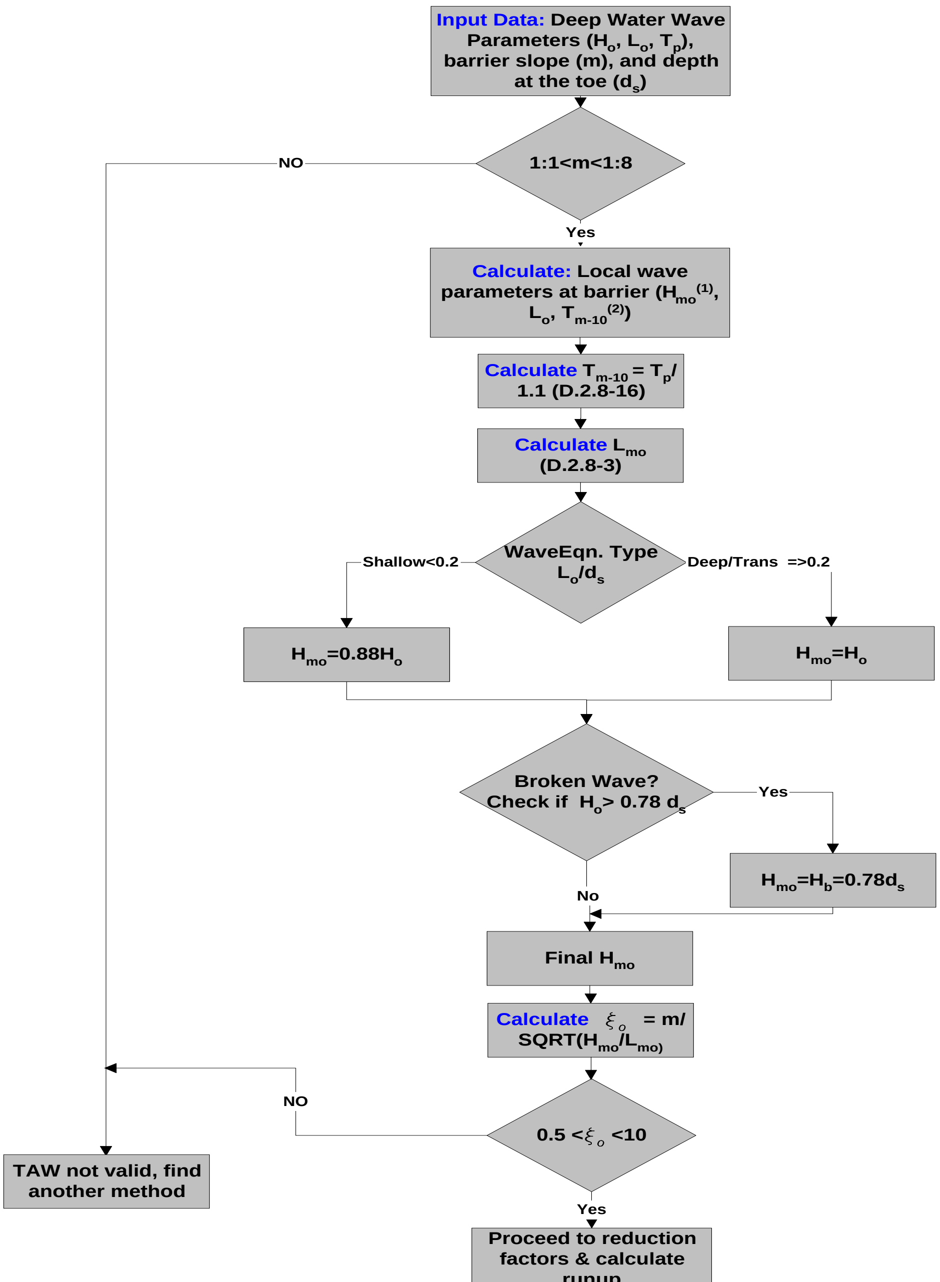
Total Final Wave Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \boxed{\eta_T = 7.4\,ft}$

Flowchart for overtopping check

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE RUNUP ON BARRIERS ANALYSIS (TAW METHOD)

Wave runup is the uprush of water from wave action on a shore barrier intercepting still water level. The presence of coastal structures/steep slopes is not unusual. The structures could be overtopped or non overtopped.The following methodology (TAW) should be used for calculating wave runup on barriers.



Flowchart for TAW method to calculate runup on barrier

To use: *edit values highlighted in green*

Transect: KT-11_F

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$d_s := 3.48ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

indicate the available information **(T or S)**

○ Deep Water Wave Steepness $S := 0.035$ Deep water wave steepness $\left(S = \frac{H_o}{L_o}\right)$ (Wave Steepness = 0.035 for extratropical storms "northeasters" and 0.040 for hurricanes)

◉ Peak Wave Period $T_p := 11.4sec$ Peak wave period (determined by STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (determined by STWAVE)

$C := 16.27ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet (NAVD)

$m := \frac{10.55}{15.45}$ Barrier slope

$$L_o := \begin{cases} \frac{H_o}{S} & \text{if } WS1 = 1 \\ \frac{g \cdot T_p^{\,2}}{2\pi} & \text{if } WS1 = 2 \\ 0 & \text{otherwise} \end{cases}$$

Deep Water Wave Length based on wave steepness input

Deep Water Wave Length based on peak wave period input

$$S := \begin{cases} S & \text{if } (WS1 = 1) \\ \frac{H_o}{L_o} & \text{if } (WS1 = 2) \\ 0 & \text{otherwise} \end{cases}$$

$$T_p := \begin{cases} \sqrt{\frac{L_o}{5.12 \cdot ft}} \cdot sec & \text{if } (WS1 = 1) \\ T_p & \text{if } (WS1 = 2) \\ 0 & \text{otherwise} \end{cases}$$

$S = 0.045$

$L_o = 665\,ft$

$T_p = 11.4 \cdot sec$

STEP 2: CALCULATE WAVE PARAMETERS AT BARRIER LOCATION

Check if broken wave

$$\text{BrokenWave} := \begin{cases} \text{"Broken"} & \text{if } H_o \geq 0.78 \cdot d_s \\ \text{"Not Broken"} & \text{if } H_o < 0.78 \cdot d_s \\ \text{"Undetermined"} & \text{otherwise} \end{cases}$$

H_b will be taken

$\text{BrokenWave} = \text{"Broken"}$

$$\text{WaveType} := \begin{cases} \text{"Shallow""} & \text{if } \frac{d_s}{L_o} < 0.2 \\ \text{"Transitional"} & \text{if } 0.2 \leq \frac{d_s}{L_o} < 0.5 \\ \text{"Deep"} & \text{if } \left(\frac{d_s}{L_o}\right) \geq 0.5 \end{cases}$$

$\text{WaveType} = \text{"Shallow""}$

$$H_{mo} := \begin{cases} H_o & \text{if WaveType} = \text{"Deep"} \\ H_o & \text{if WaveType} = \text{"Transitional"} \\ ((.88 \cdot H_o)) & \text{if WaveType} = \text{"Shallow""} \\ \text{"NONE"} & \text{otherwise} \end{cases}$$

Deep Water

Shallow Water

$H_{mo} = 26.3\,\text{ft}$

$$H_{mo} := \begin{cases} d_s \cdot 0.78 & \text{if } (\text{BrokenWave} = \text{"Broken"}) \\ H_{mo} & \text{if } (\text{BrokenWave} = \text{"Not Broken"}) \\ 0 & \text{otherwise} \end{cases}$$

H_b will be taken

H_{mo} will be taken

in case error

$H_{mo} = 2.71\,\text{ft}$

$$T_{m10} := \frac{T_p}{1.1} \qquad \text{(D.2.8-16)}$$

$T_{m10} = 10.4\,\text{s}$

$$L_{mo} := \left(\frac{g}{2 \cdot \pi}\right) \cdot T_{m10}^{\ 2} \qquad \text{(after D.2.8-3)}$$

$L_{mo} = 550\,\text{ft}$

Iribarren number, ξ_o

$$\xi_{om} := \frac{m}{\sqrt{\frac{H_{mo}}{L_{mo}}}}$$

$\xi_{om} = 9.72$

Check TAW method for Validity

TAW method will be valid if:

* 0.5< ξ_{om}<8–10

* 1:1<Barrier Slope<1:8

$$\text{TAW\_Validity} := \begin{cases} \text{"Valid"} & \text{if } \left[(0.5 < \xi_{om} < 10) \wedge (0.125 \le m \le 1)\right] \\ \text{"Not valid, Seek Another Method"} & \text{otherwise} \end{cases}$$

continue

TAW_Validity = "Valid"

STEP 3: CALCULATE REDUCTION FACTORS

In accordance to Table D.2.8-5

Roughness Reduction Factor, γ_r

- ( ) Smooth concrete, asphalt, and smooth block revetment
- (•) 1 Layer of Rock with Diameter, D. Hs/D=1 to 3
- ( ) 2 or more layers of rock Hs/D=1.5 to 6
- ( ) Quadratic Blocks

refer to CEM for accurate values

Wave Direction Factor, γ_β

$\gamma_{\beta d} := 0$ 0º for normally incident wave

- (•) Short-Crested Wave default
- ( ) Long-Crested Wave

Berm Section in Breakwater, γ_b

- (•) No Berm default
- ( ) Berm

Porosity Factor, γ_p

- ( ) P=0.1
- ( ) P=0.4
- (•) P=0.5 default
- ( ) P=0.6

other than defaults, refer to CEM for accurate values

Table D.2.8-5. Summary of γ Runup Reduction Factors

Runup Reduction Factor	Characteristic/Condition	Value of γ for Runup	
Roughness Reduction Factor, γ_r	Smooth Concrete, Asphalt, and Smooth Block Revetment	$\gamma_r = 1.0$	(D.2.8-10)
	1 Layer of Rock With Diameter, D. $H_s / D = 1$ to 3.	$\gamma_r = 0.55$ to 0.60	
	2 or More Layers of Rock. $H_s / D = 1.5$ to 6.	$\gamma_r = 0.5$ to 0.55	
	Quadratic Blocks	$\gamma_r = 0.70$ to 0.95. See Table V-5-3 in CEM for greater detail	
Berm Section in Breakwater, γ_b, B = Berm Width, $\left(\frac{\pi d_h}{x}\right)$ in radians	Berm Present in Structure Cross section. See Figure D.4.5-8 for Definitions of B, L_{berm} and Other Parameters	$\gamma_b = 1 - \frac{B}{2L_{berm}}\left[1+\cos\left(\frac{\pi d_h}{x}\right)\right], 0.6 < \gamma_B < 1.0$ $x = \begin{cases} R \text{ if } \frac{-R}{H_{mo}} \le \frac{d_h}{H_{mo}} \le 0 \\ 2H_{mo} \text{ if } 0 \le \frac{d_h}{H_{mo}} \le 2 \end{cases}$ (D.2.8-11) Minimum and maximum values of $\gamma_b = 0.6$ and 1.0, respectively	
Wave Direction Factor, γ_β, β is in degrees and = 0° for normally incident waves	Long-Crested Waves	$\gamma_\beta = \begin{cases} 1.0, 0 < \lvert\beta\rvert < 10^o \\ \cos(\lvert\beta\rvert - 10^o), 10^o < \lvert\beta\rvert < 63^o \\ 0.63, \lvert\beta\rvert > 63^o \end{cases}$ (D.2.8-12)	
	Short-Crested Waves	$1 - 0.0022\lvert\beta\rvert, \lvert\beta\rvert \le 80^o$ $1 - 0.0022\lvert 80\rvert, \lvert\beta\rvert \ge 80^o$ (D.2.8-13)	
Porosity Factor, γ_P	Permeable Structure Core	$\gamma_P = 1.0$, $\xi_{om} < 3.3$; $\gamma_P = \frac{2.0}{1.17(\xi_{om})^{0.46}}$, $\xi_{om} >$ 3.3 and porosity = 0.5. for smaller porosities, proportion γ_P according to porosity . See Figure D.2.8-7 for definition of porosity (D.2.8-14)	

Based on the seleced parameters, the reduction factors are summarized as follows:

Roughness Reduction Factor= $\gamma_r = 0.58$

Berm Section= $\gamma_b = 1$

Wave Direction Factor= $\gamma_\beta = 1$

Porosity Factor= $\gamma_p = 0.6$

Edit factors below if desired, otherwise leave as is:

$\gamma_r := \gamma_r$

$\gamma_b := \gamma_b$

$\gamma_\beta := \gamma_\beta$

$\gamma_p := \gamma_p$

STEP 4: CALCULATE RUNUP

$$R := \begin{cases} H_{mo}\cdot\left(1.77\cdot\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\xi_{om}\right) & \text{if } 0.5 \le \gamma_b\cdot\xi_{om} < 1.8 \\ H_{mo}\cdot\left[\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\left(4.3 - \dfrac{1.6}{\sqrt{\xi_{om}}}\right)\right] & \text{if } 1.8 \le \gamma_b\cdot\xi_{om} \\ 0 & \text{otherwise} \end{cases}$$

Total Final Wave Runup

$R = 3.6\,\text{ft}$

Check Overtopping

$$\text{OVERTOPPED} := \begin{cases} \text{"YES"} & \text{if } (R + \text{SWEL}) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

OVERTOPPED = "NO"

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007

$$\gamma_b := \begin{cases} 1 & \text{if } BSB = 1 \\ 0.6 & \text{if } BSB = 2 \end{cases}$$

$$\gamma_\beta := \begin{cases} (1 - 0.0022\gamma_{\beta d}) & \text{if } (|\gamma_{\beta d}| < 80) \wedge WDF \\ (1 - 0.0022 \cdot |80|) & \text{if } (80 \le |\gamma_{\beta d}| \le 90) \wedge WDF = 1 \\ 1 & \text{if } [(0 \le |\gamma_{\beta d}|) \le 10 \wedge WDF = 2] \\ \cos(|\gamma_{\beta d}| - 10) & \text{if } [(10 < |\gamma_{\beta d}| \le 63) \wedge WDF = 2] \\ 0.63 & \text{if } (|\gamma_{\beta d}| > 63) \wedge WDF = 2 \\ 0 & \text{otherwise} \end{cases}$$

$$\gamma_r := \begin{cases} 1 & \text{if } RRF = 1 \\ 0.58 & \text{if } RRF = 2 \\ 0.53 & \text{if } RRF = 3 \\ 0.70 & \text{if } RRF = 4 \\ 0 & \text{otherwise} \end{cases}$$

$$\gamma_p := \begin{cases} 1 & \text{if } (PF = 3) \wedge \xi_{om} \le 3.3 \\ \left(\left(\dfrac{2}{1.17 \cdot \xi_{om}^{0.46}}\right)\right) & \text{if } (PF = 3) \wedge \xi_{om} > 3.3 \\ 0.5 & \text{otherwise} \end{cases}$$

SaveDataWS1(data, Get_or_Save) := 2

(data Get_or_Save)

SaveDataRRF(data, Get_or_Save) := 2

(data Get_or_Save)

SaveDataWDF(data, Get_or_Save) := 1

(data Get_or_Save)

SaveDataBSB(data, Get_or_Save) := 1

(data Get_or_Save)

SaveDataPF(data, Get_or_Save) := 3

(data Get_or_Save)

$\text{SaveDataRRF}(\text{RRF}, \text{"Save"}) = 2$

$\text{RRF} = 2$

$\text{SaveDataWDF}(\text{WDF}, \text{"Save"}) = 1$

$\text{WDF} = 1$

$\text{SaveDataBSB}(\text{BSB}, \text{"Save"}) = 1$

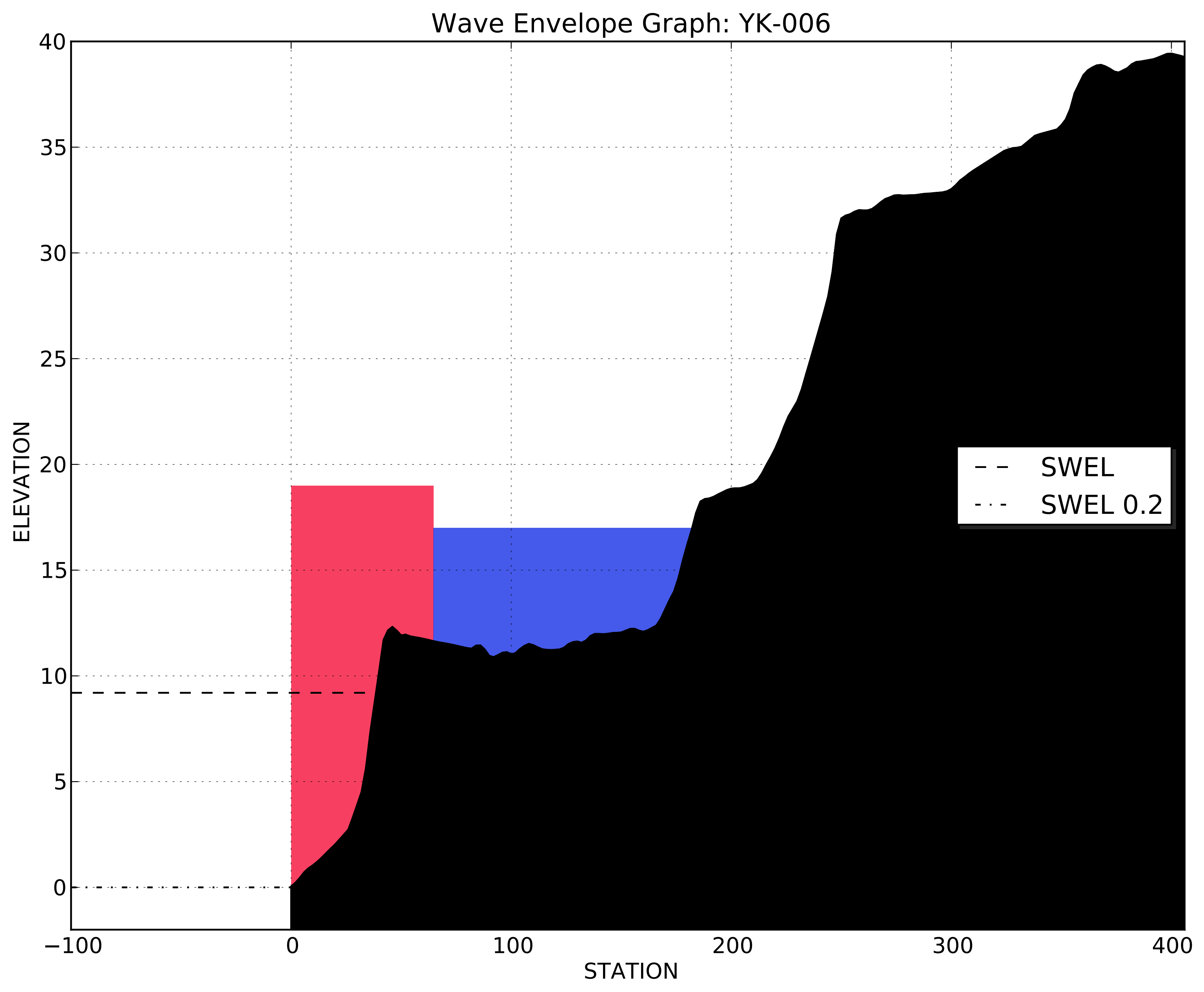
$\text{BSB} = 1$

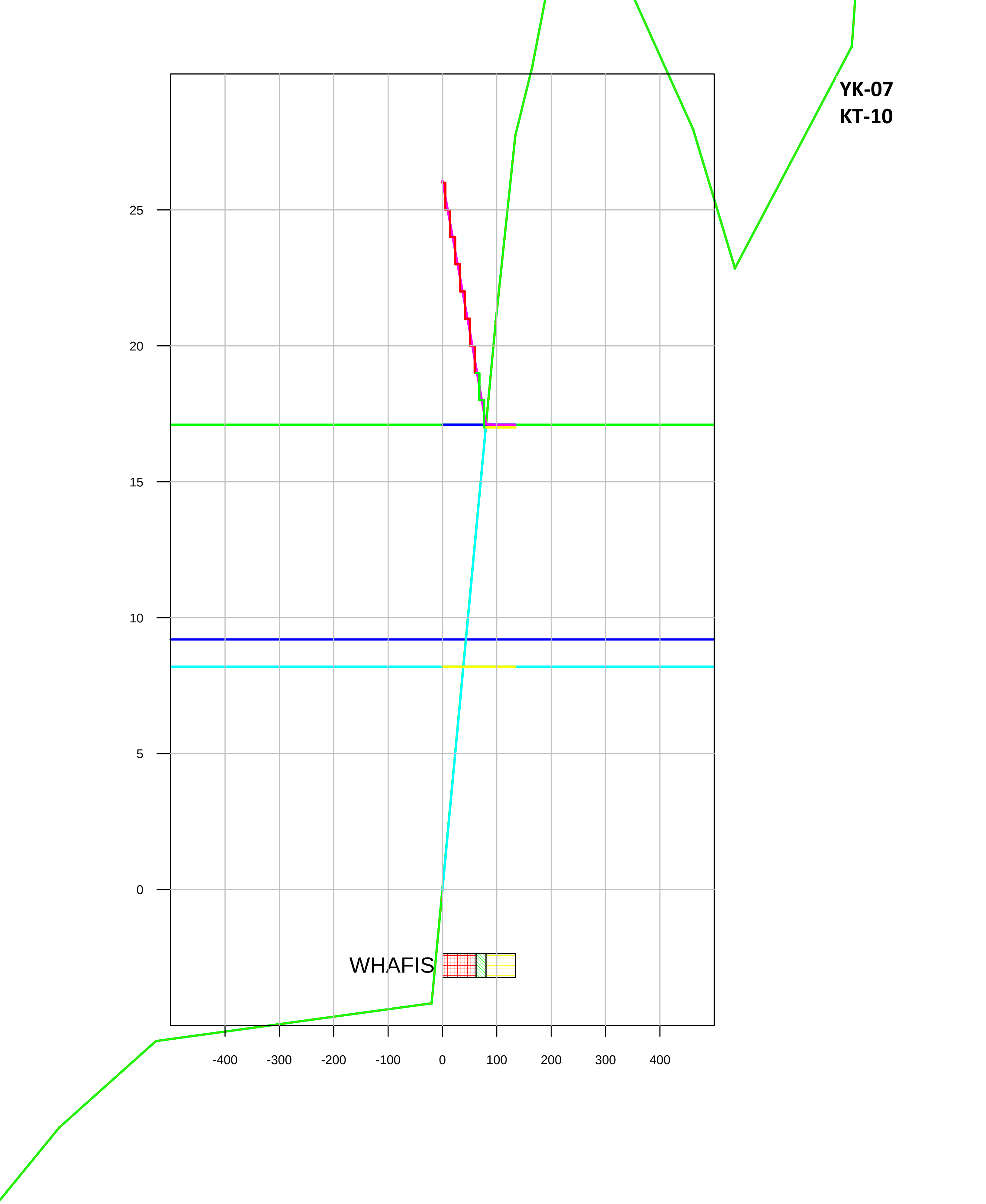
$\text{SaveDataWS1}(\text{WS1}, \text{"Save"}) = 2$

$\text{WS1} = 2$

$\text{SaveDataPF}(\text{PF}, \text{"Save"}) = 3$

$\text{PF} = 3$


Wave Envelope Graph: YK-006
ELEVATION
STATION
40
35
30
25
20
15
10
5
0
−100
0
100
200
300
400
SWEL
SWEL 0.2



YK-07
KT-10
25
20
15
10
5
0
WHAFIS
-400
-300
-200
-100
0
100
200
300
400

Project: Fema Study- York County, ME
Group: KT-9 YK-08

Case: KT-9

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	1.39	MILES
Wind Direction (WDIR)	249.27	deg
Eq Neutral Wind Speed (Ue)	63.89	mph
Adjusted Wind Speed (Ua)	104.27	mph
Mean Wave Direction (THETA)	246.00	deg
Wave Height (Hmo)	3.46	feet
Wave Period (Tp)	3.36	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	199.27	2.71
2	209.27	1.81
3	219.27	1.41
4	229.27	0.27
5	239.27	1.22
6	249.27	1.64
7	259.27	0.21
8	269.27	0.22
9	279.27	0.20
10	289.27	0.26
11	299.27	0.16

Wave Growth: Deep

YK-08

Transect General Information - Transect ID: KT-9

Description | **Parameters**

Flooding Source	Chauncey Creek		
10% chance SWEL(ft)	8.2	Source	USACE New England Tidal Prof
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE New England Tidal Prof
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE New England Tidal Prof
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	7.2	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-10

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 29.9\text{ft}$ Deepwater significant wave height (determined from STWAVE)

$T := 11.4\text{sec}$ Wave Period (determined from STWAVE)

$m := \frac{1}{5}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $Lo = 665.5\,\text{ft}$

$\frac{Ho}{Lo} = 0.04$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 6.4\,\text{ft}$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

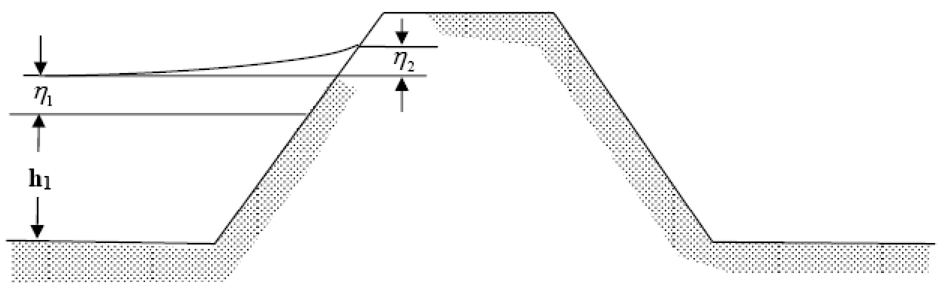


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-10 (Steep Slope)

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 6.4ft$ Wave setup without structure (From DIM MathCAD sheet for KT-10)

$h_1 := 11.2ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (from STWAVE)

$C := 20.9ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \frac{g \cdot T^2}{2 \cdot \pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

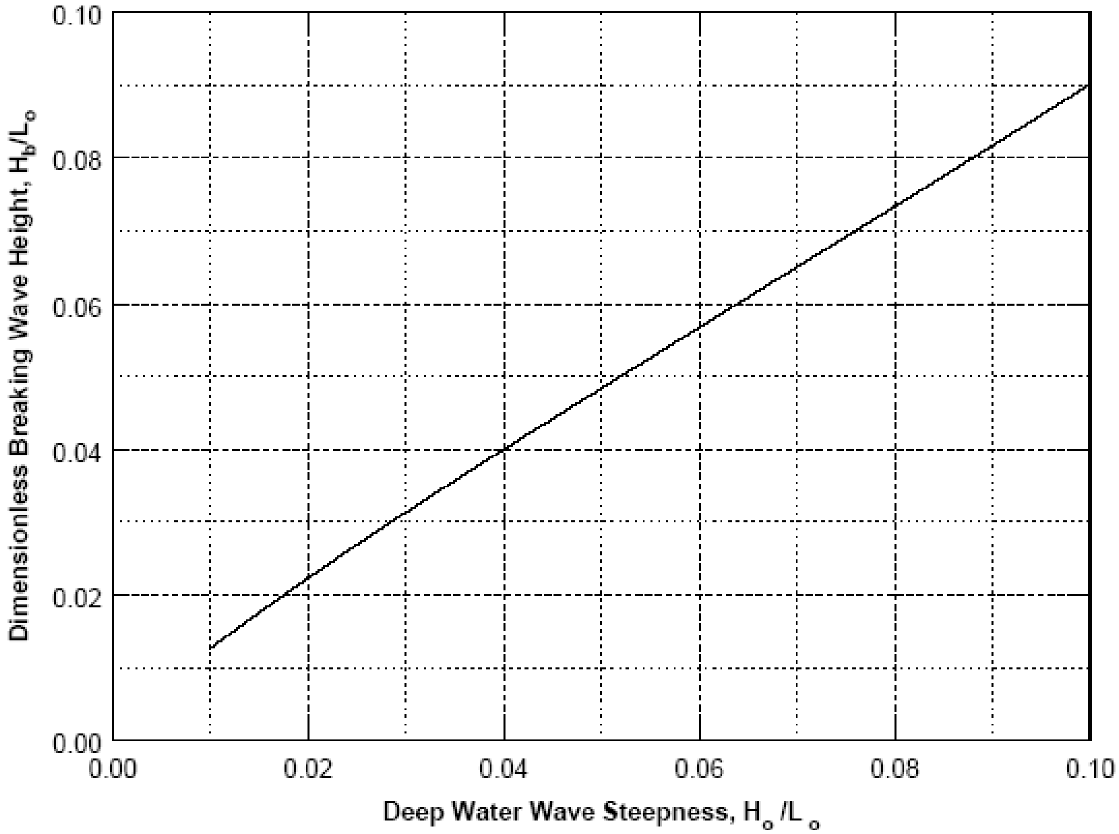


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

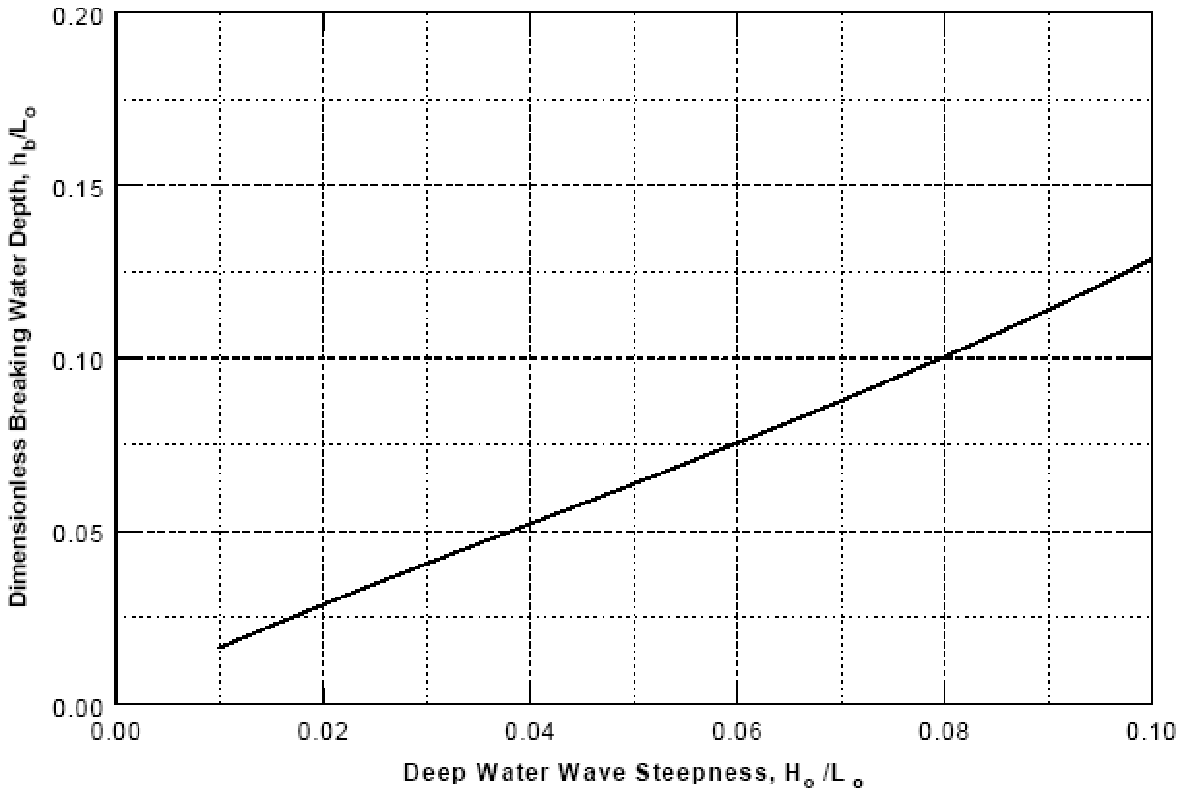


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d=h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,\text{ft}$

STEP 4: CALCULATE WAVE SETUP

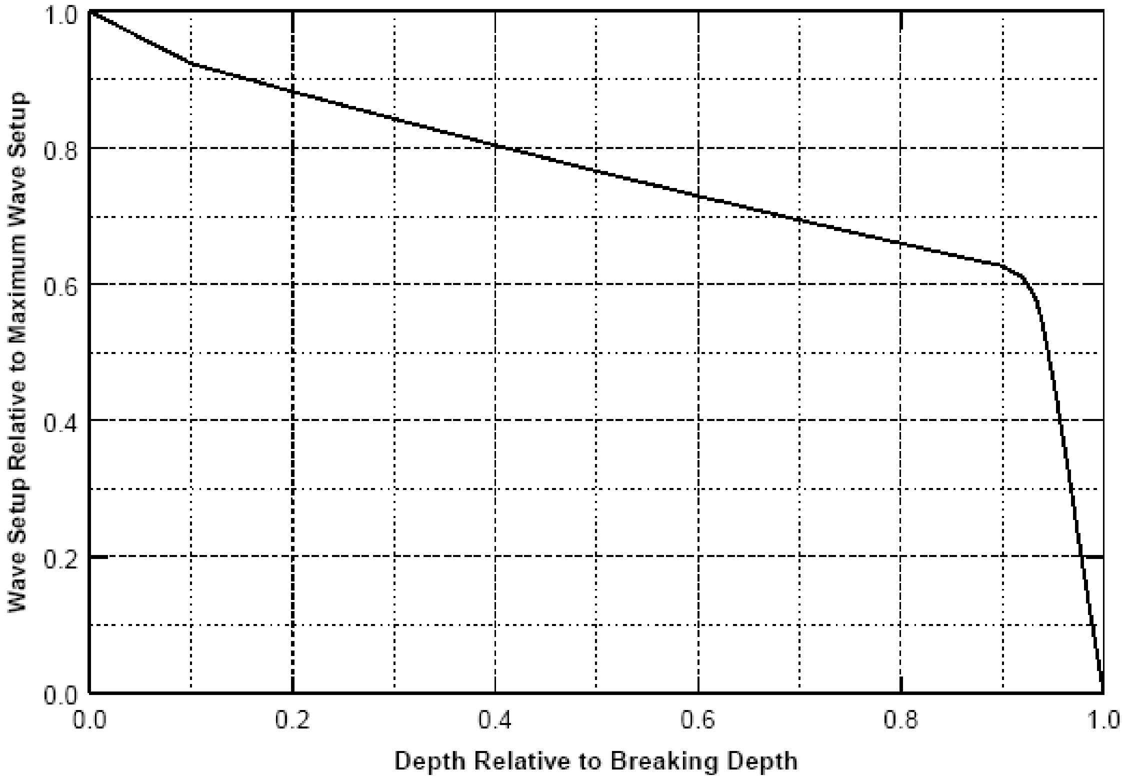


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$
R := \begin{cases}
\left[-0.8\cdot\left(\frac{h_1}{h_b}\right)+1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\
\left[-0.3919\cdot\left(\frac{h_1}{h_b}\right)+0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\
\left[-0.3475\cdot\left(\frac{h_1}{h_b}\right)+0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\
\left[-33.312\cdot\left(\frac{h_1}{h_b}\right)^2+59.811\cdot\left(\frac{h_1}{h_b}\right)-26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\
\left[-9.8703\cdot\left(\frac{h_1}{h_b}\right)+9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1
\end{cases}
$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.29$ $\quad R = 0.85$

$\eta_1 := R \cdot \eta_{max}$ $\quad \eta_1 = 5.41\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\quad \eta_2 = 2.49\,ft$

Total Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 7.9\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$

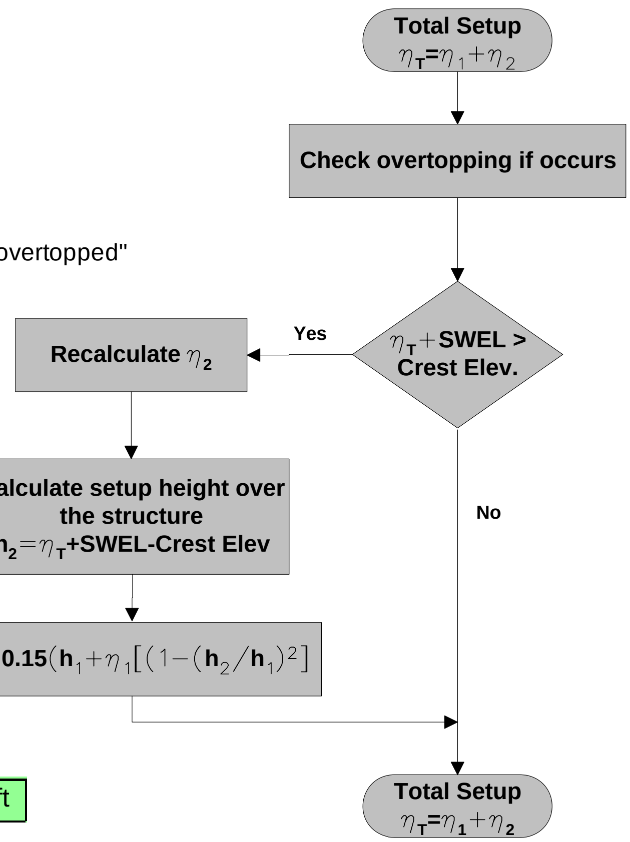
$OVERTOPPED = \text{"NO"}$

$h_2 = 0\,ft$

$\eta_1 = 5.41\,ft$

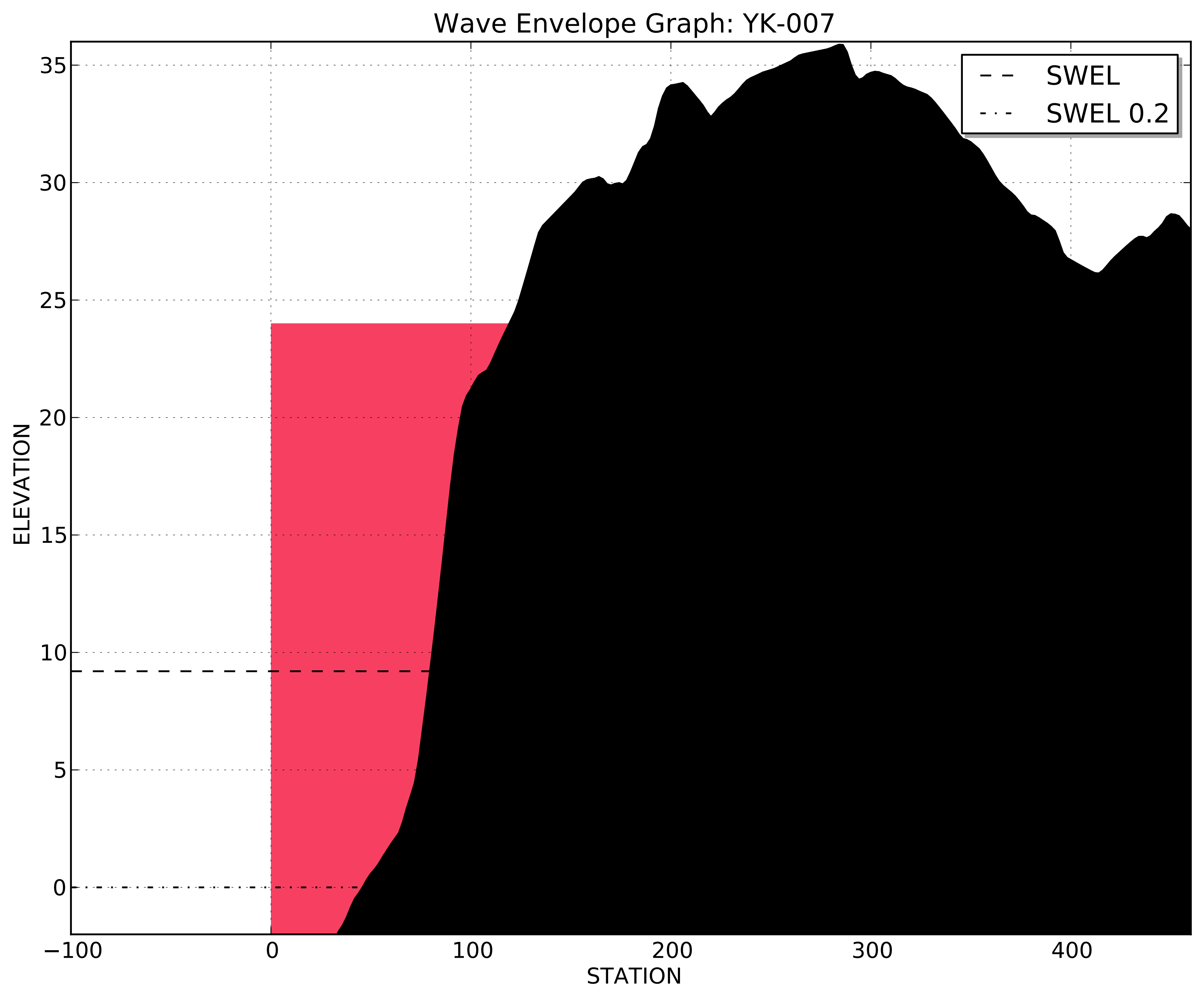
$\eta_2 = 2.49\,ft$

Total Final Wave Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \boxed{\eta_T = 7.9\,ft}$

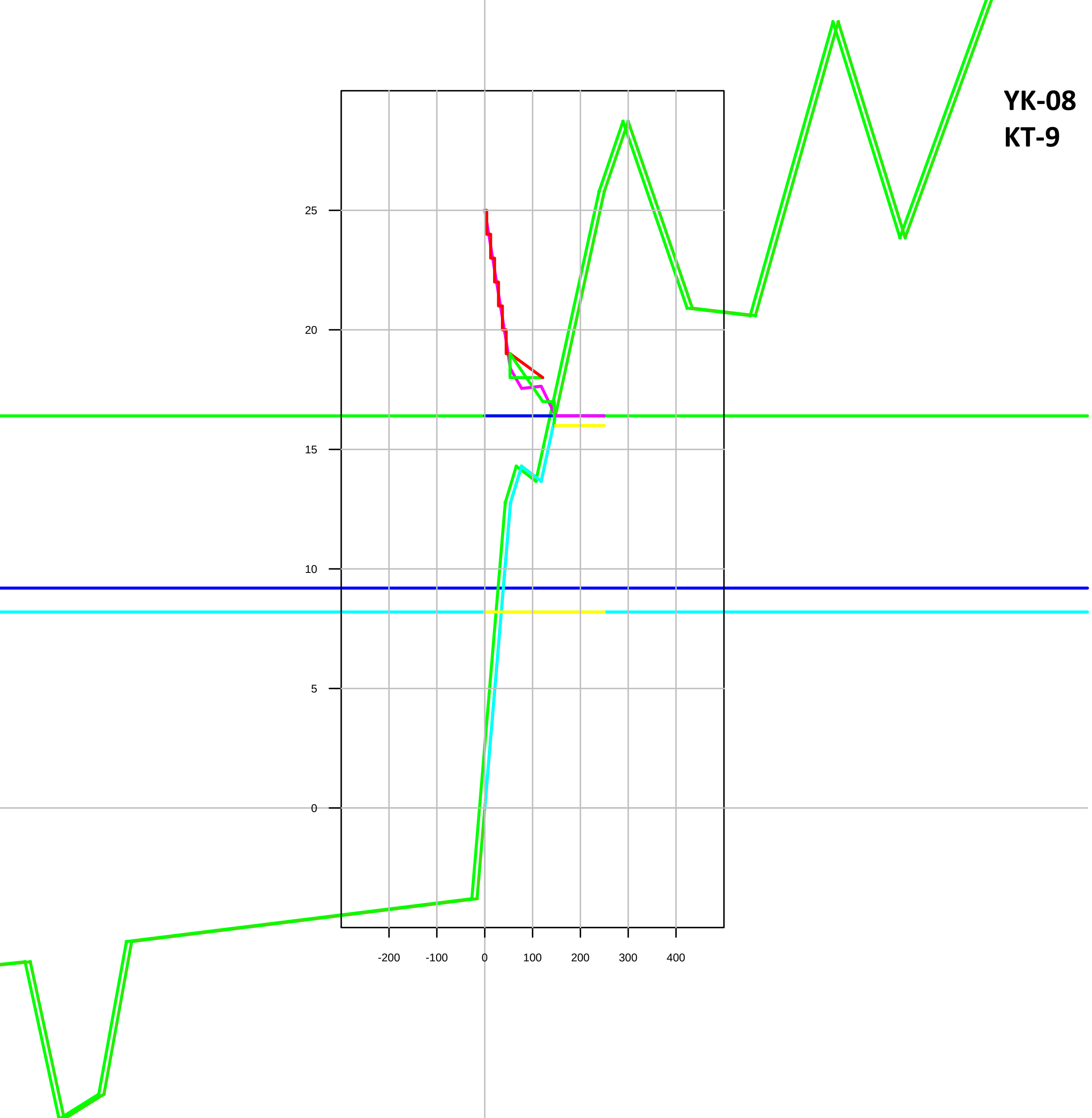


Flowchart for overtopping check

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.



Wave Envelope Graph: YK-007
SWEL
SWEL 0.2
ELEVATION
STATION
35
30
25
20
15
10
5
0
−100
0
100
200
300
400



WHAFIS

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-9

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 29.9\,ft$ Deepwater significant wave height (determined from STWAVE)

$T := 11.4\,sec$ Wave Period (determined from STWAVE)

$m := \frac{1}{3}$ Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ Deep water wave length $Lo = 665.5\,ft$

$\frac{Ho}{Lo} = 0.04$ Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 7.1\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

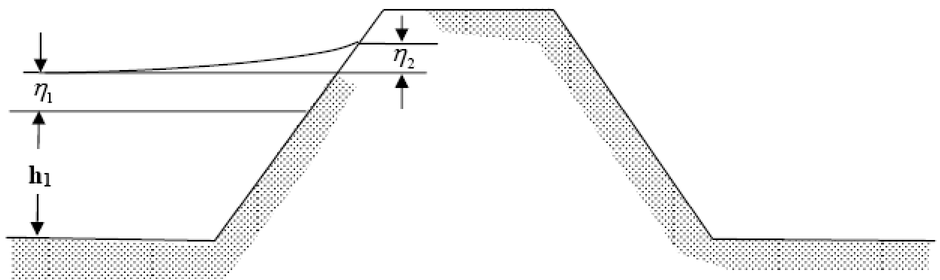


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-9 (Steep Slope)

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 7.1ft$ Wave setup without structure (From DIM MathCAD sheet for KT-9)

$h_1 := 3.95ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4 \cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (from STWAVE)

$C := 14.3ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2 \cdot ft$ Still water elevation in feet

$L_o := \dfrac{g \cdot T^2}{2.\pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

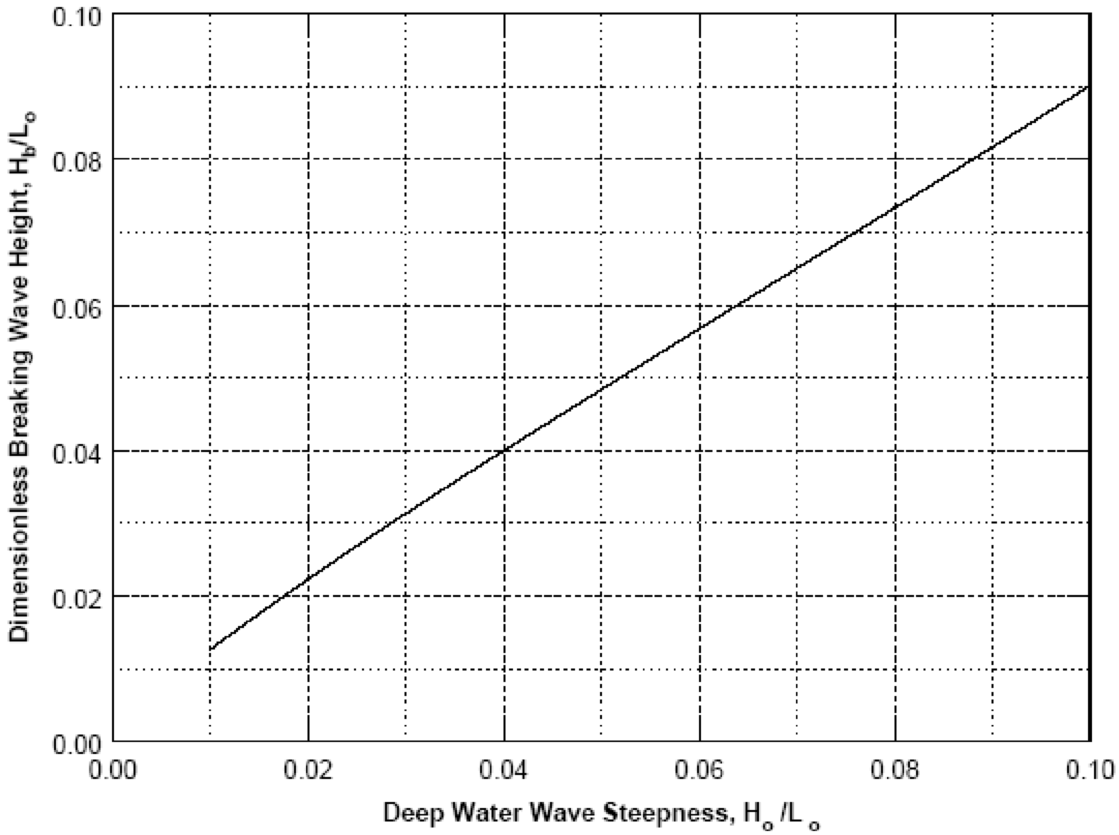


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b / L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,\text{ft}$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

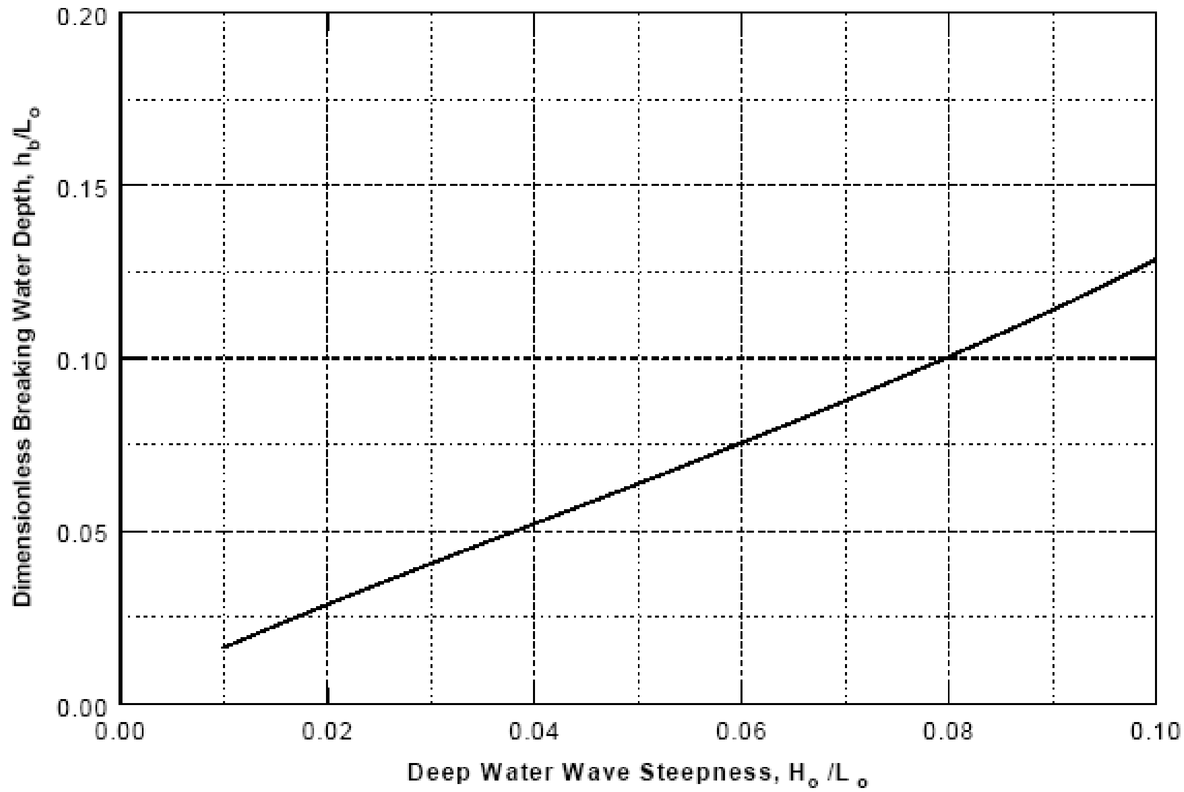


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d = h_b / L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,\text{ft}$

STEP 4: CALCULATE WAVE SETUP

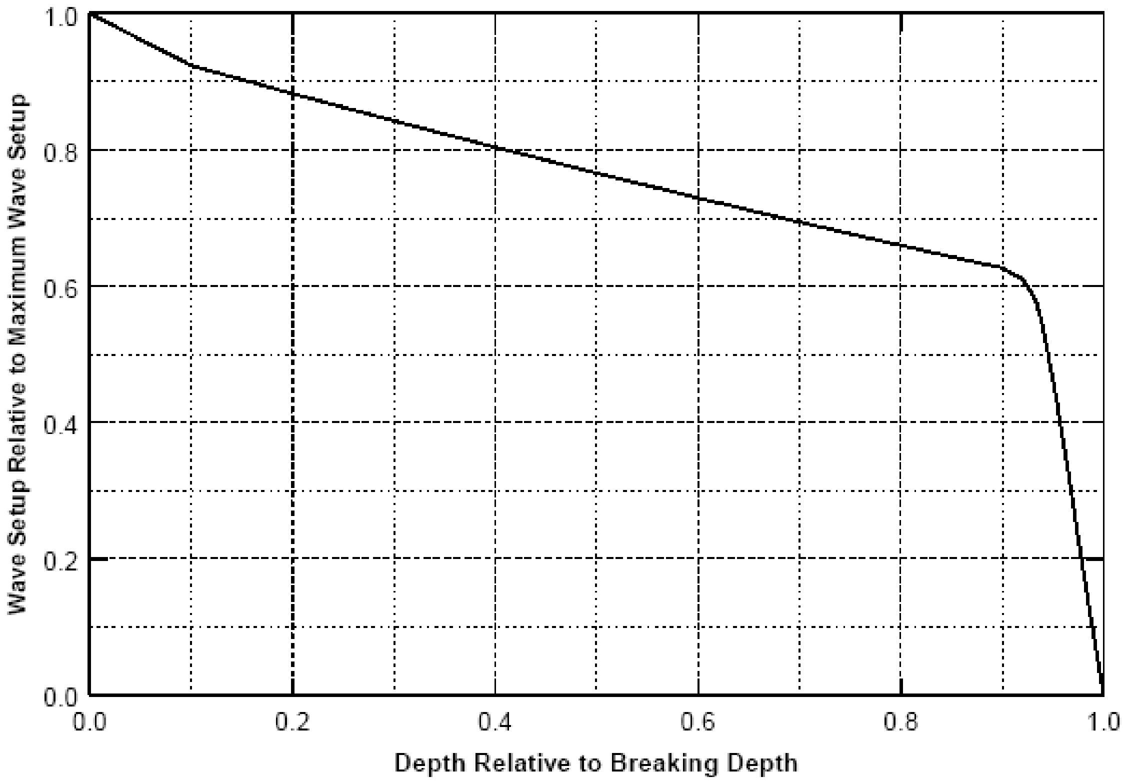


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$
R := \begin{cases}
\left[-0.8 \cdot \left(\frac{h_1}{h_b}\right) + 1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\
\left[-0.3919 \cdot \left(\frac{h_1}{h_b}\right) + 0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\
\left[-0.3475 \cdot \left(\frac{h_1}{h_b}\right) + 0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\
\left[-33.312 \cdot \left(\frac{h_1}{h_b}\right)^2 + 59.811 \cdot \left(\frac{h_1}{h_b}\right) - 26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\
\left[-9.8703 \cdot \left(\frac{h_1}{h_b}\right) + 9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1
\end{cases}
$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.1$ $\quad R = 0.92$

$\eta_1 := R \cdot \eta_{max}$ $\quad \eta_1 = 6.52\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\quad \eta_2 = 1.57\,ft$

Total Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 8.1\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$

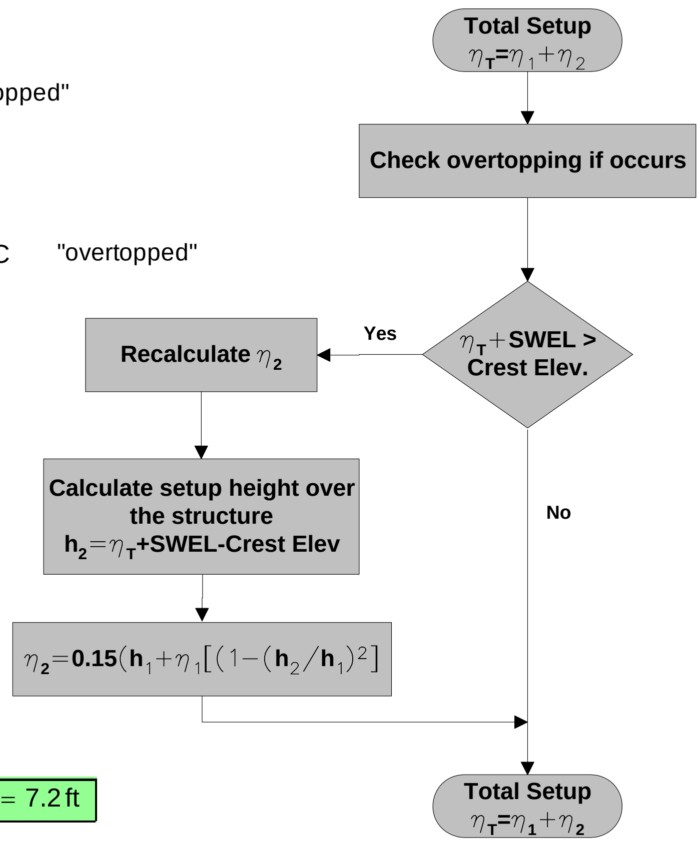
OVERTOPPED = "YES"

$h_2 = 3\,ft$

$\eta_1 = 6.52\,ft$

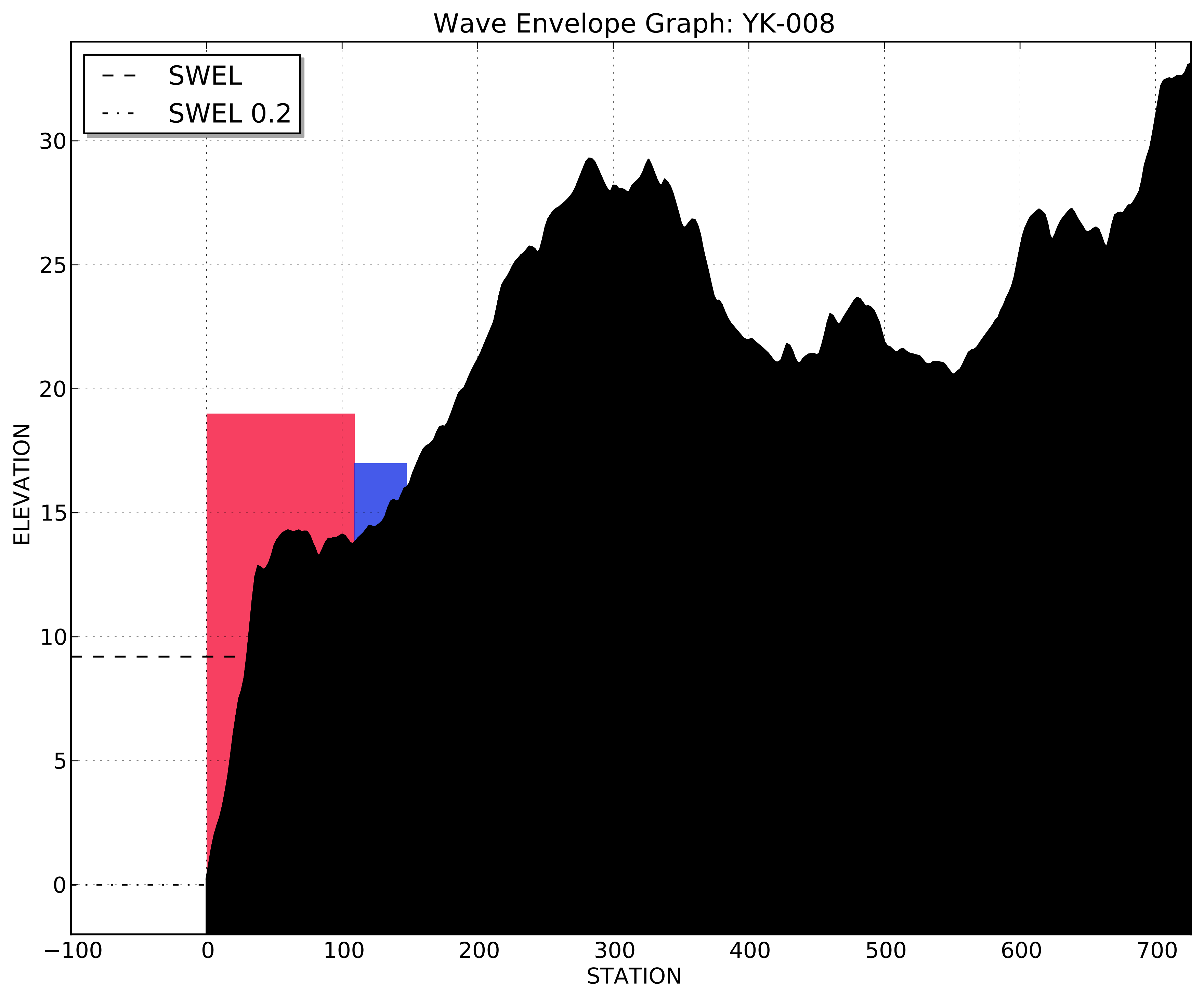
$\eta_2 = 0.67\,ft$

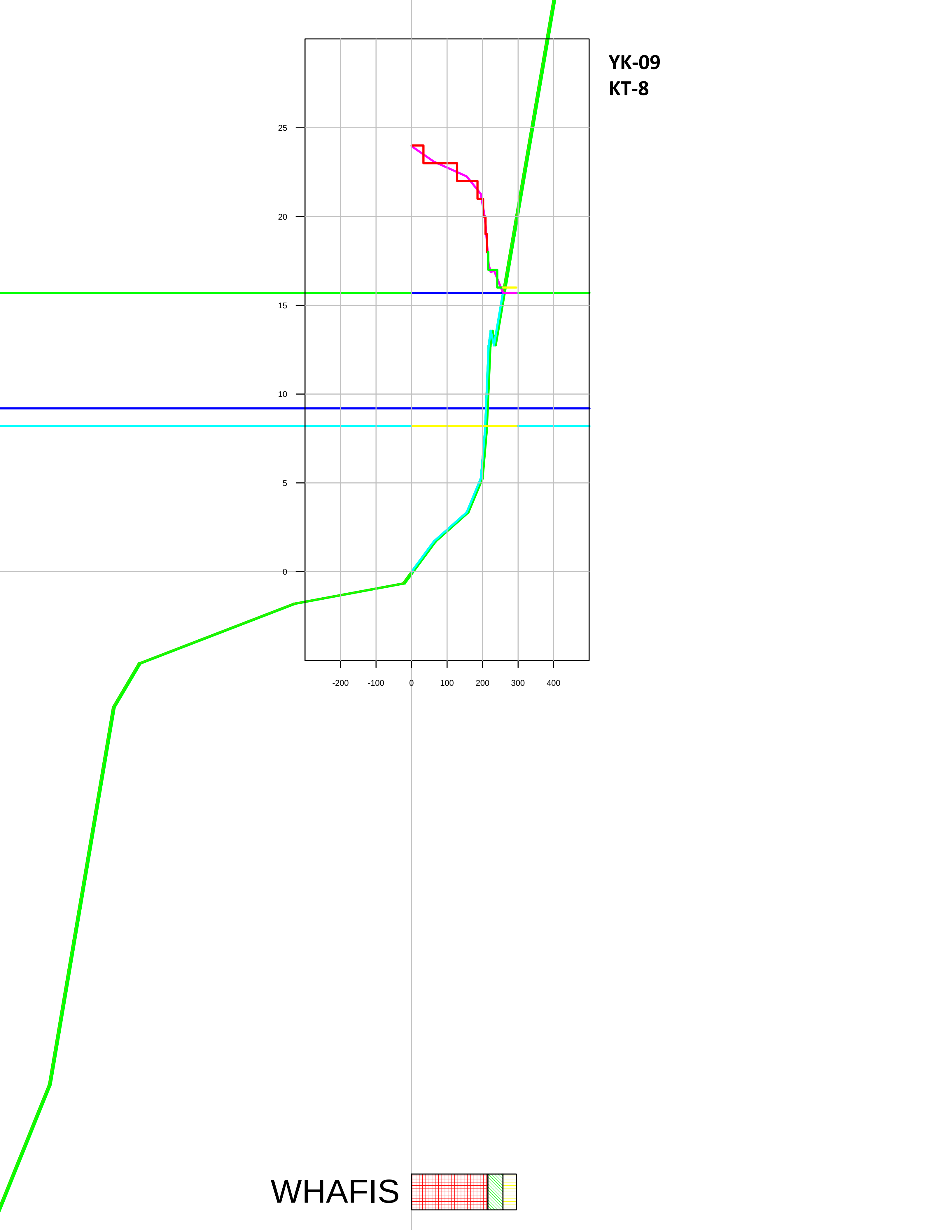
Total Final Wave Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \boxed{\eta_T = 7.2\,ft}$



Flowchart for overtopping check

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.


Wave Envelope Graph: YK-008
SWEL
SWEL 0.2
ELEVATION
STATION
30
25
20
15
10
5
0
−100
0
100
200
300
400
500
600
700



YK-09
KT-8
25
20
15
10
5
0
-200
-100
0
100
200
300
400
WHAFIS

Project: Fema Study- York County, ME
Group: KT-8 YK-09

Case: KT-8

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	71.00	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	1.00	hours
Lat. of Observation (LAT)	43.07	deg
Results		
Wind Fetch Length (F)	1.63	MILES
Wind Direction (WDIR)	277.11	deg
Eq Neutral Wind Speed (Ue)	63.89	mph
Adjusted Wind Speed (Ua)	104.27	mph
Mean Wave Direction (THETA)	281.00	deg
Wave Height (Hmo)	3.74	feet
Wave Period (Tp)	3.51	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Deep restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	227.12	1.20
2	237.12	0.97
3	247.12	0.98
4	257.11	0.81
5	267.11	0.94
6	277.11	1.70
7	287.11	1.62
8	297.11	1.01
9	307.11	0.96
10	317.11	0.87
11	327.11	0.82

Wave Growth: Deep

KT-8 YK-09

Flooding Source	Portsmouth Harbor		
10% chance SWEL(ft)	8.2	Source	USACE 100-yr New England Tid
2% chance SWEL(ft)	8.8	Source	
1% chance SWEL(ft)	9.2	Source	USACE 100-yr New England Tid
0.2% chance SWEL(ft)	9.8	Source	
Mean High Water Elev (ft)	5	Source	USACE 100-yr New England Tid
Mean Low Water Elev (ft)	-3.95	Type of Event	Northeaster
Fetch Length (mile)	0	Source of wave or fetch data	ACES Restricted Fetch Analysis
1% Significant Wave Height (ft)	29.86		
0.2% Significant Wave Height (ft)		Method for determing wave setup magnitude	Direct Integration Method (DIM) + Correction for Setup on Structures (FEMA GUIDELINES, 2007)
1% Deepwater Wave Period (sec)	11.4		
0.2% Deepwater Wave Period (sec)			
1% Wave Setup Magnitude (ft)	6.5	1% WINDVH	
0.2% Wave Setup Magnitude (ft)		0.2% WINDVH	
1% WINDOF		1% WINDIF	
0.2 % WINDOF		0.2% WINDIF	

RESTRICTED FETCH WAVE SETUP ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect to be modeled in CHAMP.

Transect: KT-8 YK-09

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 29.9\,ft$ — Deepwater significant wave height (determined from STWAVE)

$T := 11.4\,sec$ — Wave Period (determined from STWAVE)

$m := \frac{1}{4}$ — Average slope of transect (determined using GIS)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{g \cdot T^2}{2.\pi}$ — Deep water wave length $Lo = 665.5\,ft$

$\frac{Ho}{Lo} = 0.04$ — Wave Steepness

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 6.7\,ft$ — Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.

WAVE SETUP ON STRUCTURES ANALYSIS FOR KITTERY, YORK COUNTY - ME

Wave setup is an increase in the stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. Wave setup is added to the storm stillwater elevation for WHAFIS calculations, but not added to the stillwater elevation for wave runup calculations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal structure to be modeled in CHAMP where the SWEL intersects the structure.

To use: *edit values highlighted in green*

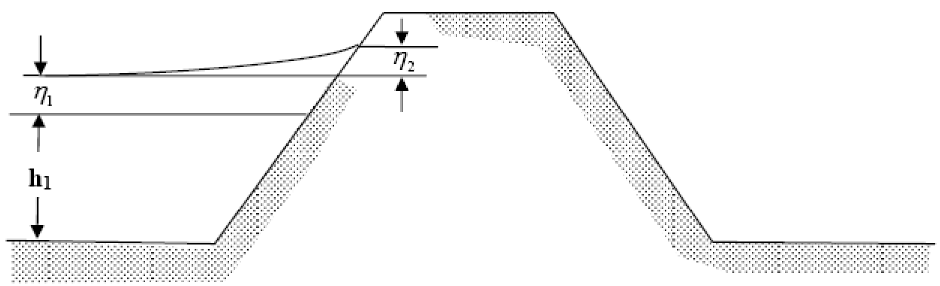


Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

NOTE: USE THE SHEET WHEN STRUCTURES OR STEEP SLOPES (1:10 OR STEEPER) INTERSECT THE SWEL

Transect: KT-8 (Steep Slope)

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$\eta_{max} := 6.7ft$ Wave setup without structure (From DIM MathCAD sheet for KT-8)

$h_1 := 3.78ft$ Depth at structure/slope toe. (Calculate as: SWEL-elevation of toe)

$T := 11.4\cdot sec$ Deep water wave period (from STWAVE)

$H_o := 29.9ft$ Deep water significant wave height in feet (from STWAVE)

$C := 13.5ft$ Crest of the structure/slope elevation in feet

$SWEL := 9.2\cdot ft$ Still water elevation in feet

$L_o := \frac{g\cdot T^2}{2.\pi}$ Deep water wave length $L_o = 665.5\,ft$

$S := \frac{H_o}{L_o}$ Deep water wave Steepness $S = 0.045$

STEP 2: CALCULATE BREAKING WAVE HEIGHT (H_b)

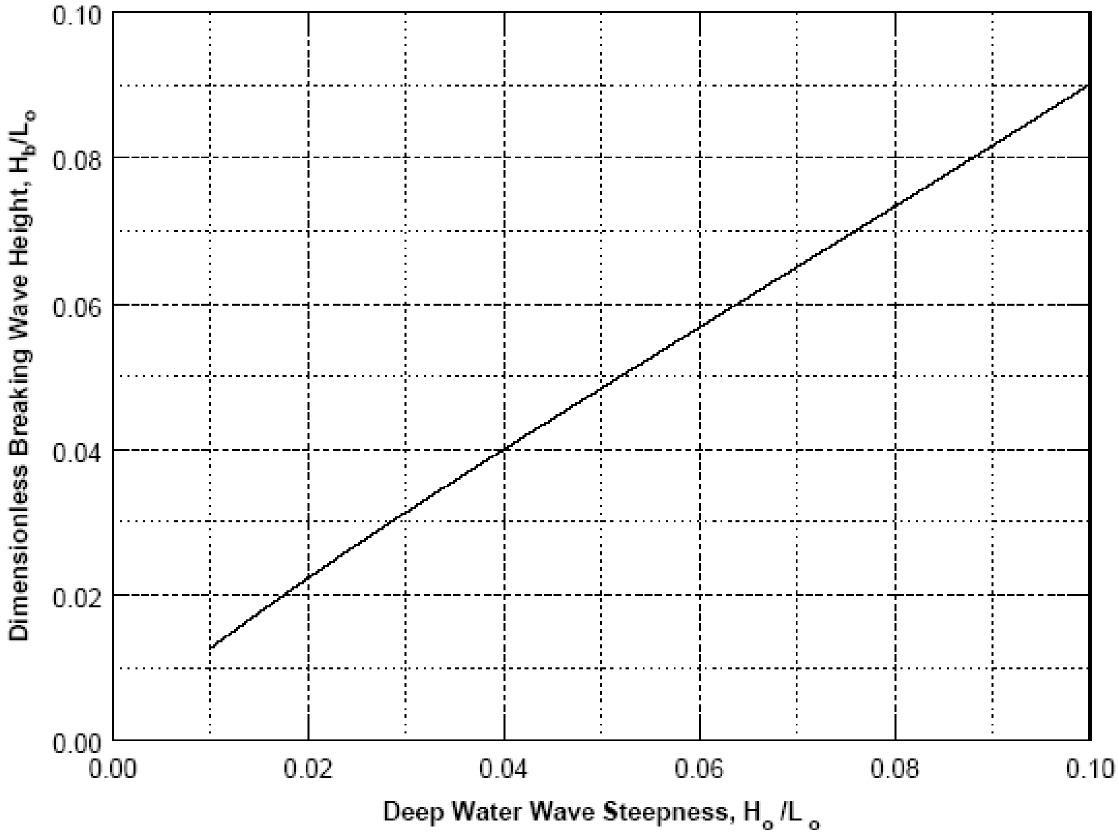


Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

Dimensionless breaking wave height $b_h = H_b/L_o$

$b_h := 0.8481 \cdot S + 0.0057$ Estimated curve equation in figure D.2.6-7

$b_h = 0.044$

$H_b := b_h \cdot L_o$

$H_b = 29.2\,ft$

STEP 3: CALCULATE BREAKING DEPTH (h_b)

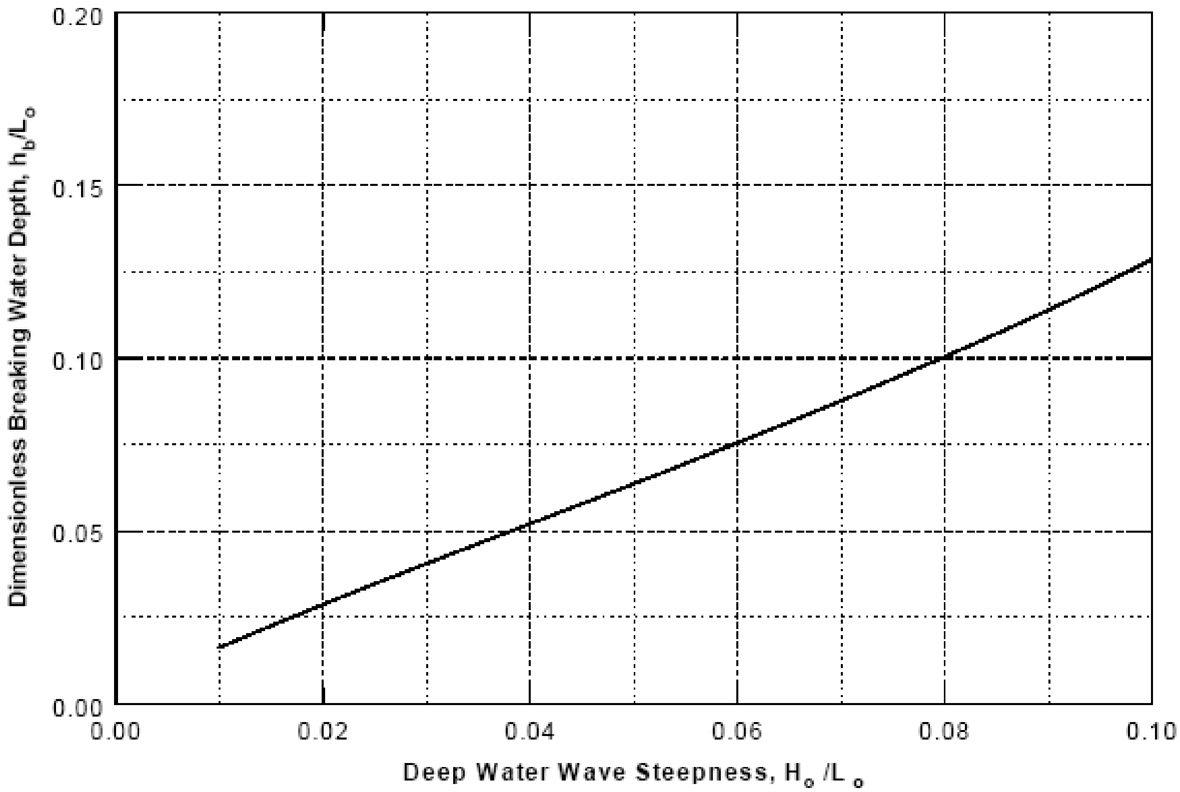


Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

Dimensionless breaking wave depth $b_d=h_b/L_o$

$b_d := 1.2205 \cdot S + 0.0033$ Estimated curve equation in figure D.2.6-8

$b_d = 0.058$

$h_b := b_d \cdot L_o$

$h_b = 38.7\,\text{ft}$

STEP 4: CALCULATE WAVE SETUP

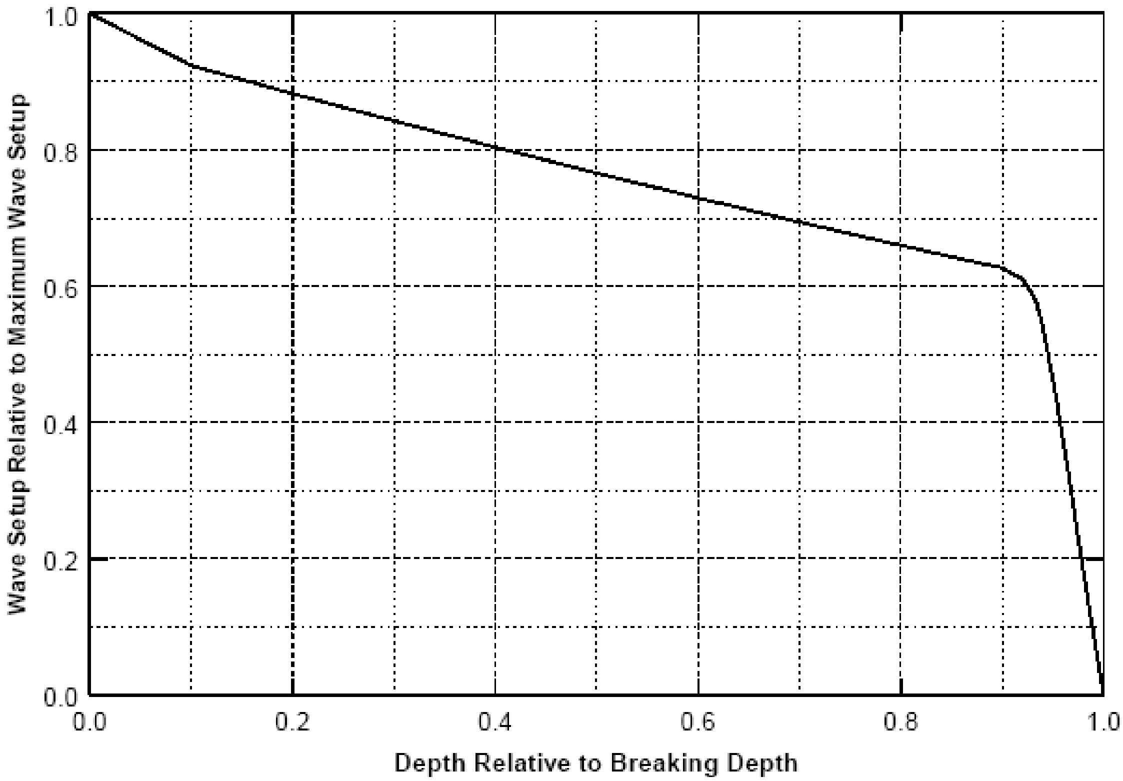


Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

Wave Setup vs. Maximum Wave Setup ratio ($R := \frac{\eta_1}{\eta_{max}}$)

$$R := \begin{cases} \left[-0.8 \cdot \left(\frac{h_1}{h_b}\right) + 1\right] & \text{if } \left(\frac{h_1}{h_b}\right) \le 0.092 \\ \left[-0.3919 \cdot \left(\frac{h_1}{h_b}\right) + 0.9585\right] & \text{if } 0.092 < \left(\frac{h_1}{h_b}\right) \le 0.4 \\ \left[-0.3475 \cdot \left(\frac{h_1}{h_b}\right) + 0.9379\right] & \text{if } 0.4 < \left(\frac{h_1}{h_b}\right) \le 0.9 \\ \left[-33.312 \cdot \left(\frac{h_1}{h_b}\right)^2 + 59.811 \cdot \left(\frac{h_1}{h_b}\right) - 26.223\right] & \text{if } 0.9 < \left(\frac{h_1}{h_b}\right) \le 0.94444 \\ \left[-9.8703 \cdot \left(\frac{h_1}{h_b}\right) + 9.8703\right] & \text{if } 0.94444 < \left(\frac{h_1}{h_b}\right) \le 1 \end{cases}$$

Estimated curve equation in figure D.2.6-9

For $\frac{h_1}{h_b} = 0.1$ $\quad R = 0.92$

$\eta_1 := R \cdot \eta_{max}$ $\quad \eta_1 = 6.17\,ft$

$\eta_2 := 0.15 \cdot (h_1 + \eta_1)$ $\quad \eta_2 = 1.49\,ft$

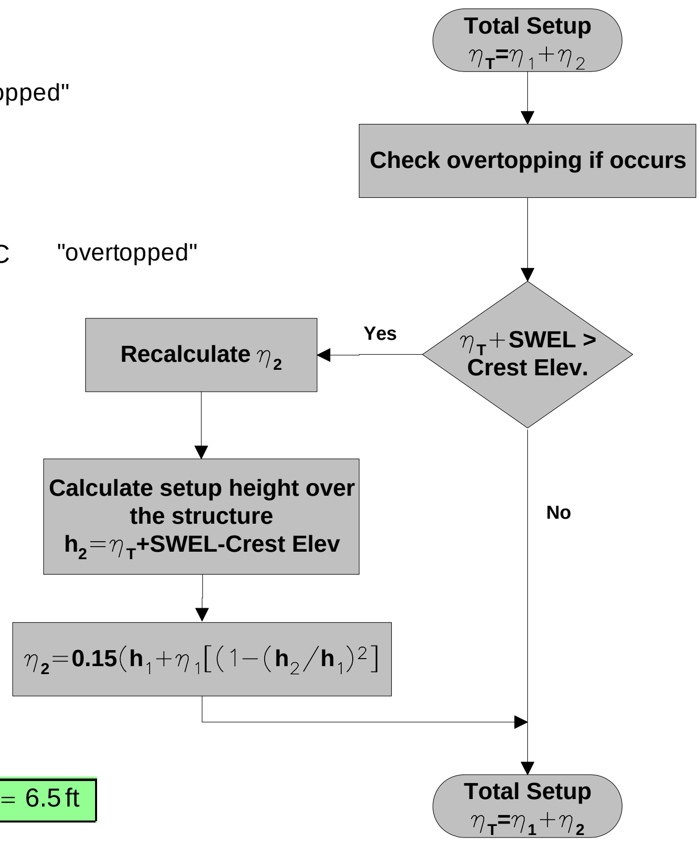
Total Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \eta_T = 7.7\,ft$

Check overtopping

$$OVERTOPPED := \begin{cases} \text{"YES"} & \text{if } (\eta_T + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$$h_2 := \begin{cases} (\eta_T + SWEL - C) & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ 0 & \text{otherwise} \end{cases}$$

$$\eta_2 := \begin{cases} 0.15 \cdot (h_1 + \eta_1) \cdot \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] & \text{if } (\eta_T + SWEL) > C \quad \text{"overtopped"} \\ \eta_2 & \text{otherwise} \end{cases}$$



Flowchart for overtopping check

OVERTOPPED = "YES"

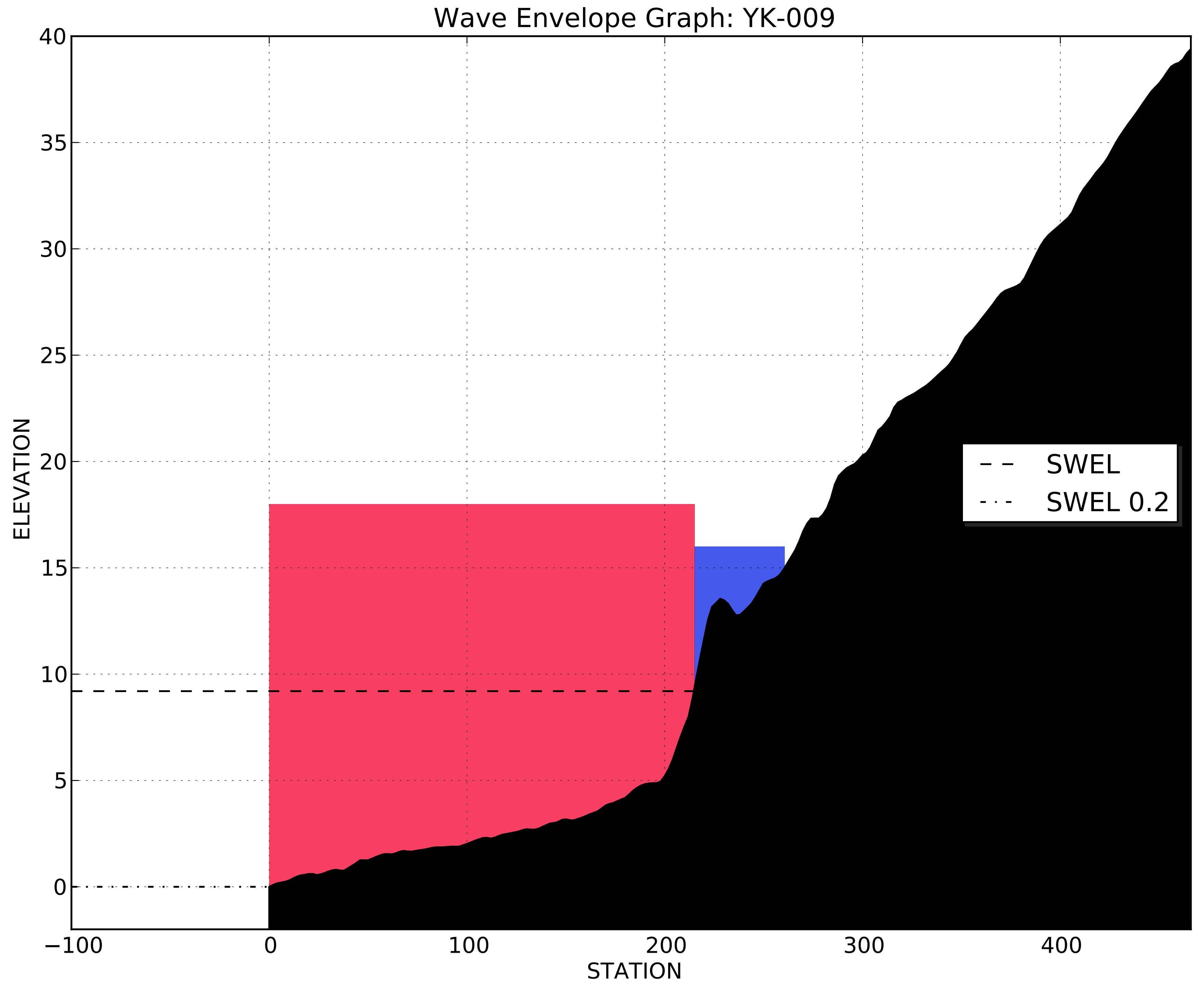
$h_2 = 3.4\,ft$

$\eta_1 = 6.17\,ft$

$\eta_2 = 0.32\,ft$

Total Final Wave Setup $\quad \eta_T := \eta_1 + \eta_2$ $\quad \boxed{\eta_T = 6.5\,ft}$

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007.



Wave Envelope Graph: YK-009
40
35
30
25
20
15
10
5
0
−100
0
100
200
300
400
ELEVATION
STATION
SWEL
SWEL 0.2

D.2.7 Overland Wave Propagation

This subsection provides guidance for estimating wave heights and wave crest elevations on flooded land areas. FEMA's WHAFIS model is described.

D.2.7.1 Overview

The fundamental analysis of overland wave effects for an FIS is provided by the WHAFIS 3.0 program, a DOS-based program that uses representative transects to compute wave crest elevations in a given study area. Transects must be specified by the Mapping Partner, who must also identify topographic, vegetative, and cultural features along each transect landward of the shoreline. WHAFIS uses this and other input information to calculate wave heights, wave crest elevations, flood insurance risk zone designations, and flood zone boundaries along the transects (FEMA, 1988). The Mapping Partner can specify an incident wave height, or WHAFIS can compute an incident wave height at the seaward end of each transect. Please note that the WHAFIS-calculated incident wave height is based on the fetch provided by the Mapping Partner and does not take into account refraction, diffraction, or bottom dissipation effects. The Mapping Partner should perform separate wave transformation calculations if these effects will cause the incident wave height to depart markedly from the value generated by WHAFIS. The Mapping Partner should consult FEMA's approved wave model list at http://www.fema.gov/plan/prevent/fhm/en_coast.shtm if additional wave studies are required.

The original basis for the WHAFIS model was the 1977 NAS report *Methodology for Calculating Wave Action Effects Associated with Storm Surges*. The NAS methodology accounted for varying fetch lengths, barriers to wave transmission, and the regeneration of waves over flooded land areas. Because the incorporation of the NAS methodology into the initial version of WHAFIS, periodic upgrades have been made to WHAFIS to incorporate improved or additional wave considerations. Figure D.2.7-1 illustrates the basic factors that WHAFIS considers in its overland wave height and wave crest elevation calculations.

The current WHAFIS model is fully documented (*Technical Documentation for WHAFIS Program Version 3.0*, FEMA, September 1988). Briefly, the wave action conservation equation governs wave regeneration caused by wind and wave dissipation by marsh plants in the model. This equation is supplemented by the conservation of waves equation, which expresses the spatial variation of the wave period at the peak of the wave spectrum. The wave energy (equivalently, wave height) and wave period respond to changes in wind conditions, water depths, and obstructions as a wave propagates. These equations are solved as a function of distance along the wave analysis transect.

od $T_{m-1.0}$. For 'normal' spectra with a clear peak, $T_{m-1.0}$ lies close to the peak period T_p and a conversion factor is given for a case for which only the peak period is known.
- Using the above-mentioned spectral period, it is no longer necessary to have a procedure for double-peaked or bi-modal spectra, and this procedure has been removed.
- Formulae for wave run-up and wave overtopping have been adjusted to the use of the above mentioned parameters, specifically:
  - The maximum for wave run-up lies higher than in the previous versions and progresses more fluidly from breaking to non-breaking waves.
  - The formulae for wave overtopping have only been adjusted to use of the above mentioned parameters. For shallow and very shallow foreshores separate formulae are given.

These last changes have been justified in a background report [DWW, 2001].

1.2 Definitions

In the list of symbols short definitions of the parameters used have been included. Some definitions are so important that they are explained separately in this section. The definitions and validity limits are specifically concerned with application of the given formulae. In this way, a slope of 1:12 is not a slope and it is not a berm. In such a situation, wave run-up and wave overtopping can only be calculated by interpolation. For example, for a slope of 1:12, interpolation can be made between a slope of 1:8 (mildest slope) and a 1:15 berm (steepest berm).

Foreshore

A foreshore is a part in front of the dike and attached to the dike, and can be horizontal or up to a maximum slope of 1:10. The foreshore can be deep, shallow or very shallow. In the last case, the limits of depth mean that a wave can break on this foreshore and the wave height is therefore reduced. The wave height that is always used in wave run-up and wave overtopping calculations is the incident wave height that should be expected at the end of the foreshore (and thus at the toe of the dike).

Sometimes a foreshore lies very shallow and is rather short. In order for a foreshore to fall under this definition, it must have a minimum length of one wavelength L_0. After one wavelength, the wave height would be reasonably adjusted to the shallow or very shallow foreshore and the wave height at the end of this foreshore can be used in the formulae. If the shallow or very shallow foreshore is shorter, then interpolation must be made between a berm of $B = 0.25.L_0$ and a foreshore with a length of $1.0.L_0$. In the Guidelines [TAW, 1989], a minimum length of 2 wavelengths was used and it was suggested that, for a shorter length than one wavelength, no reduction for wave height would be applied and the foreshore would be ignored. Current insight suggests rather that most waves will break on a shallow or very shallow foreshore within one wavelength and that this wavelength can be used as the lower limit.

A precise transition from a shallow to a very shallow foreshore is hard to give. At a shallow foreshore waves break and the wave height decreases, but still a wave spectrum exists with more or less the shape of the incident wave spectrum. At very shallow foreshores the spectral shape changes drastically and hardly any peak can be detected (flat spectrum), as the waves become very small due to breaking and many different wave periods arise. Generally speaking the transition between shallow and very shallow foreshores can be indicated as the situation where the original incident wave height, due to breaking, has been decreased by 50% or more.
The wave height at a structure on a very shallow foreshore is much smaller than in deep-